Vol. 45 JANUARY, 1952 No. 3

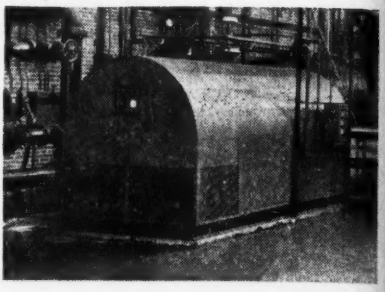
NATIONAL FIRE PROTECTION ASSOCIATION

Quarterly

Published Quarterly at Boston, Mass., by the
NATIONAL FIRE PROTECTION ASSOCIATION
International

Experience...

backed by thousands of installations!



CARDOX

LOW PRESSURE Carbon Dioxide FIRE EXTINGUISHING SYSTEMS*

THE LEADERS RELY ON CARDOX

- To protect 14 of the nation's 25 largest power stations.
- To safeguard 38 of the nation's 50 leading industrial corporations.
- To keep hundreds of other plants fire-safe.

TRANSITANK

AIRPORT FIRE TRUCK

FIRE TRUCK

The CARDOX Corporation many years ago pioneered and made available *low pressure* carbon dioxide fire extinguishing systems.

And from never-ending, far-ranging research came new methods, new techniques, new viewpoints — all perfected by CARDOX. During these years thousands of systems have been engineered, manufactured and installed by CARDOX.

As a result, when it comes to fire protection by low pressure carbon dioxide —and the hazards large or small for which this extinguishing agent offers so many advantages — CARDOX experience and knowledge are *undisputed* and *unduplicated*.

Whenever you plan fire protection, make sure you get the benefit of this experience and knowledge. Call in CARDOX!

*Covered by CARDOX patents, issued and pending

CARDOX CORPORATION

Bell Building • Chicago 1, Illinois

District Offices in Principal Cities

Property of Library
Cooper Union for the
Advancement of Science
and Art

Volume 45 January 1952 Number 3

Quarterly

The Standard Technical Journal of Fire Protection for More Than Forty Years

of the

National Fire Protection Association

Subscriptions accepted only as part of membership dues of the Association. Annual dues: $12.50 of which $5.00 is for subscription to this journal.

National Fire Protection Association
International

60 Batterymarch Street Boston 10, Mass., U.S.A.

Entered as second-class matter December 15, 1928, at the Post Office at Boston, Mass., and Framingham, Mass., under act of March 3, 1879.

Copyright, 1952, National Fire Protection Association

National Fire Protection Association
International

OFFICERS

A. H. S. STEAD
President

ALLEN L. COBB
Vice-President

T. SEDDON DUKE
Vice-President

HOVEY T. FREEMAN
Secretary-Treasurer

RICHARD E. VERNOR
Chairman Board of Directors

STAFF

PERCY BUGBEE
General Manager

ROBERT S. MOULTON
Technical Secretary

HORATIO BOND
Chief Engineer

CHARLES S. MORGAN
Assistant General Manager

WARREN Y. KIMBALL
Manager, Fire Services Dept.
Editor, Firemen

GEORGE H. TRYON, III
Assistant Technical Secretary

MELVIN R. FREEMAN
Public Relations Manager

CHESTER I. BABCOCK
Fire Record Dept. Manager

HENRY S. GERE
Advertising Manager

RICHARD E. STEVENS
Fire Record Dept.

PAUL R. LYONS
Associate Editor, Firemen

CHARLES L. SMITH
Electrical Field Engineer

STANLEY EARLE
Flammable Liquids Engineer

BEATRICE L. FINLEY
Chief Clerk

PHYLLIS L. DE PLOEY
Asst. to Technical Secretary

The National Fire Protection Association is a non-profit technical and educational organization devoted to the reduction of loss of life and property by fire with more than 13,000 members. The *Quarterly* is one of the publications regularly provided to members. Other membership publications include a monthly *Fire News, Advance Reports* and *Proceedings* of the Annual Meetings, a *Year Book,* and many leaflets, pamphlets and posters issued throughout the year on fire prevention and control.

Technical committees of the Association develop means to safeguard life and property through the publication of standards covering all phases of fire prevention and protection. Your membership in the Association (annual dues $12.50) affords an opportunity to keep abreast of these developments and, by being a member, you help support this humanitarian activity. Popular educational literature on fire safety is constantly being produced by the NFPA for distribution through its members to the general public.

All members of the Association and the public are invited to NFPA meetings. The following dates are now on the Calendar:

NFPA Calendar

1952	
June 9-13	Annual Meeting, Hotel Statler, N. Y.
Oct. 27-29	Regional Meeting, Cleveland, O.
Dec. 1-3	Regional Meeting, Houston, Tex.
1953	
May 11-15	Annual meeting, Palmer House, Chicago.

The closing date for articles submitted for the *Quarterly* is the 15th of the month preceding publication.

QUARTERLY
of the
NATIONAL FIRE PROTECTION ASSOCIATION

ROBERT S. MOULTON.....*Editor*
GEORGE H. TRYON, III.....*Associate Editor*
MARGUERITE C. CHAFFIN.....*Editorial Assistant*
HENRY S. GERE.....*Advertising Manager*

Volume 45 **January 1952** **Number 3**

Table of Contents

Fire Prevention Week Winners.....Frontispiece
Fire Protection Developments in 1951, *Percy Bugbee*..... 185
Fire Problems of 1952, *Robert S. Moulton*..... 188
NFPA Standards a Bar Against Communism, *Thomas M. Torrey*..... 192
Fire Safety in Tank Truck Design, *T. A. Burress*..... 194
Gasoline Tank Truck Fire Record..... 202
British Fire Tests of Fibreboard..... 218
Protecting Closed Vessels Against Explosions
E. W. Cousins and P. E. Cotton..... 225
"Emergency — Dr. Red" — St. Paul's Hospital Fire, Dallas..... 232
Kodak Park Paper Storage Fire..... 235
Large Loss Fires of 1951..... 244
Manufacturing 245
Storage 255
Mercantile 264
Habitational 268
Transportation 269
Miscellaneous 271
Factors Contributing to Large Structural Fires..... 277
Fire Gas Research Report..... 280
The Effect of Exposure to Heat..... 282
Causes of Deaths in Fires..... 289
Carbon Monoxide and Carbon Dioxide..... 292
Specific Gas and Vapor Hazards..... 294
Emergency Treatment 299
Index to Advertisers..... 306

Accounts of fires appearing in the Quarterly are copies of or extracts from reports forwarded to the Association except where otherwise indicated. The Association, as a body, is not responsible for the statements or opinions of any of its members. This publication is indexed by Engineering Index, Inc.

Entries of the winners in the NFPA International Municipal Fire Prevention Week contest are shown in the photo-montage. Fort Wayne's entry, 1951 U. S. Grand Award winner, forms the base of the schematic fire triangle. Entries from Chicago, Louisville, Alameda, Tuscaloosa, and Atlantic (Iowa) are on the left and Canadian winners Ottawa, Grand Award, Canada, Hull (Quebec), Arvida (Quebec), Kenora (Ontario) and Kentville (N.S.) are on the right.

Vol.

The Quarterly

Vol. 45 January 1952 No. 3

Fire Protection Developments in 1951

By Percy Bugbee, General Manager
National Fire Protection Association

The Committee on Fire Casualty Statistics and the Fire Record Department of NFPA have been working on obtaining more accurate statistics on deaths and injuries from fires and are working towards the universal acceptance of a model reporting form for fire casualties. The best estimates from these sources for the fire fatalities during 1951 in the United States and Canada stand at 12,518. In the light of all of our present knowledge of fire hazards and how to eliminate them, this is certainly a disgraceful record.

Losses Greatest in History

The preliminary estimates of property losses for the year are $823,500,000 of which $742,000,000 is in buildings and contents and $81,500,000 in outdoor fires such as fires in aircraft, motor vehicles and forest and brush fires. These figures compare with a building and contents loss of a year ago estimated at $699,600,000 and an outdoor fire loss of $76,840,000, noticeable increases in both items. The total dollar value of loss for last year is greater than any previous year in history, but, of course, such figures must be used with a full understanding of the effects of inflation, and it is our general opinion that in amount of property destruction we are probably better than holding our own.

The Fire Record Department of NFPA estimates that there were approximately 302 fires during 1951 with a loss of a quarter of a million dollars or more. This compares with the figure of 243 such fires in 1950, an increase of 24 percent and the largest number in history.

Some Bad Examples

There were a number of individual fires that attracted widespread interest and attention during the year. The first of these occurred in Lansing, Mich. on February 8 when the state office building was very seriously damaged with a very large loss of state records. While this fire was set by one of the employees, weaknesses in the construction and protection of the building and inadequate record protection equipment combined to produce the serious loss, this in spite of the fact that some years previously the state fire marshal had made recommendations pointing out the hazards in the building. (See April 1951 *Quarterly*, page 288.)

The second of these fires occurred in Montreal on June 15 in a Catholic hospice. This fire took the lives of 35 persons and

again was an example of poor construction and inadequate built-in protection. (See July 1951 *Quarterly,* page 31.)

The Newark, N. J. propane terminal fire of July 7 involved some 70 large tanks, each 70 feet long and 105 inches in diameter, and was perhaps the most spectacular fire of the year. (See July-August 1951 *Fire News,* page 5.)

The series of gas explosions in Brighton, N. Y., a suburb of Rochester, on September 21 caused two deaths and several injuries plus considerable destruction of a group of substantial dwellings. This incident offered numerous interesting lessons to students of fire protection. (See October 1951 *Quarterly,* page 85.)

U. S. Fire Departments

So far as our municipal fire departments are concerned, the number of changes in working hours and pay did not appear to be nearly as evident or pronounced as during the previous year. With the advent of the NPA and materials control, there arose considerable confusion and difficulty with respect to the purchase of municipal fire apparatus, and many cities found it difficult to place orders and to forecast when orders, if placed, would be filled. There are indications this situation may improve.

The trend to more extensive and effective fire prevention work in fire departments mentioned in recent surveys has continued during the past year and was greatly stimulated by a special campaign for reduction of deaths to children in fires instituted by the International Association of Fire Chiefs. This campaign was specifically pointed at the inspection of dwellings by fire departments, a procedure that has proven highly effective in the cities that have instituted it and one that can be carried on with no extra expense to the taxpayers. We are hopeful that this movement will expand very rapidly and become universally accepted by fire departments everywhere, as most deaths and injuries from fire occur in private dwellings.

Some fruitful conferences have been held between representatives of the building officials of the country and the city fire marshals and fire prevention bureau chiefs to iron out conflicts of jurisdiction which often exist between those two agencies. This activity has been fostered by the NFPA.

New NFPA Standards

A substantial body of new standards of particular interest to the states and cities were developed by various NFPA committees during the past year. The 1951 edition of the National Electrical Code made its appearance and was very widely adopted throughout the country. The new National Fire Codes issued by the NFPA on Extinguishing and Alarm Equipment, Building Construction and Equipment, and Flammable Liquids, Gases, Chemicals and Explosives, embody all of the standards in these important three fields and are widely used as reference material for legislation. New Standards on Motor Fire Apparatus, on Liquefied Petroleum Gases, and on Oil Burning Equipments were developed and a new edition of the model Flammable Liquids Ordinance made its appearance.

Interest in legislation controlling fireworks continues with new state laws adopted during the year in Oregon and Colorado. The City of Los Angeles adopted a comprehensive Dangerous Chemical Code covering some 2,000 chemicals.

By Teachers for Teachers

Great advances were made during 1951 in the field of public education in fire waste control. A very important development has been the issuance by the National Education Association of four manuals on fire safety prepared by teachers for teachers

and covering primary grades, intermediate grades, junior high school and senior high school teachers. The widespread acceptance of this material by teachers is bound to have a long-range effect upon the habits of our people.

The acceptance by the Advertising Council of a campaign on home fire prevention with the NFPA as the sponsor secured during the past year valuable radio and television time, magazine and newspaper space for fire prevention on a scale never previously attained. This campaign is on a year-round basis and we expect will gain increasing momentum during 1952.

Fire Contests

Awards for excellence among cities for year-round fire prevention activity are made by the National Fire Waste Council in April of each year. The awards for 1950 for the various classes of population were to Houston, Texas, Atlanta, Ga., Hartford, Conn., Bethlehem, Pa., Parkersburg, W. Va., and Fort Collins, Colo., with the City of Detroit, Mich. the grand winner.

Fire Prevention Week in October was more widely observed throughout the United States and Canada than any year in its long history and thousands of communities filed entries with the NFPA in the Fire Prevention Week Contest. The grand winners in the United States and Canada were respectively: Fort Wayne, Ind., Ottawa, Ontario, and the winning U. S. cities by classes of population were: Class 1: Chicago, Ill., Class 2: Louisville, Ky., Class 3: Fort Wayne, Ind., Class 4: Alameda, Calif., Class 5: Tuscaloosa, Ala., Class 6: Atlantic, Iowa. For Canada: Class A: Ottawa, Ont., Class B: Hull, Que., Class C: Arvida, Que., Class D: Kenora, Ont., Class E: Kentville, Nova Scotia.

A unique development in the field of publicity during the year was the conducting of a joint contest for fire photographs by the NFPA and the National Press Photographers Association. This contest aroused great interest and brought a large and very valuable collection of spectacular and educational fire photographs and is being continued. The NFPA published the "1951 Photo Contest Fire Photographs" in NFPA Pamphlet No. E15.

Defense Awareness Lags

The situation with respect to civil defense is of special interest to fire authorities because of the very great importance of the fire aspects of modern warfare. Civil defense developments of 1951 were extremely spotty with rather spectacular strides being made in individual states and cities but with an overall lag and apathy that was evident throughout the year.

I think it is safe to say that the civil defense authorities, particularly on the federal and state levels, have not for the most part created public awareness and enthusiasm for a real civil defense effort in this country. It is to be hoped that during the coming year the public can be made to realize that we are subject to a devastating attack upon our cities because of new developments in weapons which radically change the whole conception of war. Should we ever be subjected to such an attack, numerous and large-scale fires are inevitable. Fortunately the training of the mass population in simple fire fighting measures is sound and constructive whether we are ever attacked or not.

New Activities

Special new developments of the year initiated by the National Fire Protection Association include a program in the field of flammable liquids instituted in the late fall of 1950 and carried through in 1951 with conspicuous success.

The new Society of Fire Protection En-

gineers launched by the Association in the early spring of 1951 has aroused widespread interest among fire protection engineers. This Society is intended to secure recognition of this special branch of engineering by state licensing boards and others concerned with fire protection.

Perhaps the most useful and practical of all special publications for fire inspectors of all kinds is the NFPA Fire Inspection Manual which made its appearance during the year and which is widely used.

The issuance of the fifth edition of the Municipal Fire Administration text by the International City Managers Association is worthy of special mention because this textbook has become a standard for municipal fire administration practices.

Fire Problems of 1952

By Robert S. Moulton

The beginning of a new year, while of itself bringing no new problems in the field of fire protection, is an appropriate time to pause for a review of some of the fundamental problems of fire prevention and fire protection that confront all of us during the year 1952. The following summary covers a few items which seem of particular significance as indicated by the inquiries received by the NFPA Executive Office. They are by no means all of the fire problems that require current attention, but are particularly challenging and should be of concern to every fire protection engineer, to all the members of the NFPA, and to fire authorities generally.

These special items have been selected for discussion in this article as being of particular current interest but not with any thought that they are necessarily any more important than many other fire problems. This selection should not be construed as any lack of appreciation of the never-ending problems of public education in fire prevention, better public and private fire protection, the continual need for better housekeeping, and all of the thousand and one other items that are the constant concern of the fire prevention inspector.

The Atom Bomb

The fire problem of the atom bomb is a stupendous one. We are all greatly concerned about the possible fire effects of atomic attack and those who are most familiar with the subject realize how devastating such fire can be. People generally are concerned and are groping for some answer but have had little real guidance beyond the very common-sense suggestion that if our centers of industry and our population were so dispersed that they were no longer an attractive target, the fire problem would largely be eliminated. Any systematic attempt at dispersal by government edict seems out of the question at present except perhaps in the cases of a few key industrial operations. Real estate values and vested interests generally would stand to lose too much by any drastic change in the present congested pattern of American cities.

While there has been some rather intelligent defense planning, as far as the general public is concerned, about the only visible attempt to deal with the fire aspects of atomic attack to date is the placing of signs indicating the location of shelters, specifying emergency highway routes, etc. This is

quite characteristic of the common approach to fire problems by the lay public which all too often seems to think that all that needs to be done is to post suitable signs and that the fire problem will thereby be solved. Signs do, of course, have their place and if a liberal posting of signs reading: "Fires are not permitted to start here" gives added peace of mind to the occupants of buildings, perhaps it is a good thing, provided only that such signs do not operate to detract attention from real fire safety measures.

The Tax-Free Factory

American industry is being dispersed to some extent, not primarily by reason of any specific fear of atomic attack nor to any government activity, but due to the increasing expense and difficulty of operation of large industrial enterprises in urban areas. The increasing local tax burden, difficulty in compliance with all sorts of codes and regulations, parking and labor problems, provide a powerful incentive to industry to move out into the country.

While this industrial dispersion is highly desirable from the war angle, it often presents a serious peace-time fire problem which the fire record shows all too clearly is getting worse year by year. The factory in the rural area outside the city is often erected with no legal restrictions as to type of construction or occupancy and thus may present a greater inherent hazard. It is located in a rural area where there is no good public water supply and public fire protection is apt to be quite inadequate as judged by city standards. The designers of such factories in rural areas all too frequently fail to realize that they cannot have buildings of greater combustibility and place them in an area with less public protection without being subject to the penalty of greater fire losses. The answer here is obvious — that of providing a complete automatic sprinkler system or other private protection. Fortunately many of the more progressive managements have recognized this necessity.

Acres of Fire

The increasing size of buildings, particularly industrial and storage structures, is such that areas of buildings must often be measured in acres rather than square feet. Large-area structures present an increasing fire problem, particularly where the contents are combustible and reliance is placed on fire department protection which is limited by economic factors and should not be expected to cope with fire of such magnitude. Industrial designers call attention to the advantages of large manufacturing and storage areas under one roof. The problem is to make the fire protection keep pace with such new developments. In many cases really adequate fire protection for such large areas would be so costly that subdivision of areas is the only practical answer.

The High Pile

Mechanization of industrial and storage operations has now proceeded to the point where material handling is largely by means of mechanical equipment rather than by manpower. That ingenious gadget, the fork lift truck, has made it possible to carry all sorts of merchandise around and boost it up to the top of high piles, greatly increasing the amount of storage possible in a given area as compared with the days when the height of storage piles was pretty much limited to a man's reach.

Where the material stored is combustible, this brings an aggregation of fuel in one spot which presents a fire problem far beyond anything that was contemplated when the protection for the storage struc-

ture was designed. Not only do we have in these high piles a larger concentration of combustible material, but the pallets used themselves provide combustible material and air spaces through which fire can travel out of the reach of automatic sprinklers or hose streams. The fork lift truck is without doubt here to stay because of its vast savings in labor. The problem is now for fire authorities to find some way of offsetting the hazard of the high pile.

The Open Door

The open door is a traditional invitation to the stranger to enter and unfortunately this principle operates where the stranger is fire just as it does for the tired wayfarer. In new buildings, stairways are now quite largely enclosed, the building code writers having now learned the necessity of this elementary feature of fire safety. But, the wooden wedge under the bottom of the door in the stairway enclosure to a large measure invalidates the entire program of protection of vertical openings. Stair doors are found blocked open in every sort of building in every part of the country.

Those buildings where the character of maintenance is such as to keep doors closed, or the design of the building is such that there is no incentive for occupants to block the doors open, are the exception rather than the rule. Inspectors remove wooden wedges by the bushel and the next day the doors are again open with more wedges. Fire protection people should realize the seriousness of this problem and there should be some engineering solution to it. Education, of course, should be continued and intensified and some people might even suggest legislation making it a crime to have a wooden wedge in one's possession. However, there should be some mechanical answer. A fusible link door closer is one answer, but it is subject to the objection that it does not operate in case of fire quickly enough to prevent the passage of large quantities of smoke which may create a life hazard. Quick-operating devices functioning on the rate-of-rise or electronic principle might operate quickly enough but are expensive and involve complicated maintenance problems. The old-fashioned smokeproof tower might be an excellent answer except that people don't like to go out on open balconies in cold weather. Door releases could be connected with automatic sprinkler or fire alarm systems, but this again might involve maintenance difficulties. The overall problem of the open door seems to the writer to be one of the most serious of current fire problems and one unfortunately which has received comparatively little fundamental attention.

Explosive Insulation

Some kinds of insulation board, largely used for interior finish in inexpensive construction, can burn so fast that people have suspected the presence of explosives. The problem is to treat the material to reduce its surface combustibility to that of ordinary wood, or less, without prohibitive increase in cost, or material decrease in thermal insulating value. As a result of research by manufacturers, considerable progress has been made in developing flame-reducing treatments. However, there still remains the serious problem of the use of combustible adhesives and binders with noncombustible products such as mineral wool and particularly the use of tar paper vapor seals that can burn with explosive rapidity.

The Oil Stove

Small domestic oil stoves, largely those having pot type burners, are being used to a greater and greater extent and are taking an increasing toll in loss of life by flash fires. The regular oil burner of the type

listed by Underwriters' Laboratories and installed in accordance with NFPA standards has a relatively favorable record. The trouble is with the small, cheaply made, unapproved devices, often improperly installed in small homes, with careless handling of the fuel, lack of proper maintenance of the stoves, operation with inadequate ventilation and other defects, which are combining to make the oil stove perhaps the greatest single factor today in loss of life by fire in the poorer class of dwellings. The answer to this problem appears to lie in fire department educational activities such as have been conducted by the Memphis Fire Department with excellent results, in securing the cooperation of the manufacturers in making a better product, and perhaps in some legal control over defective equipment and improper installation.

The Burning Aircraft

Fire continues to be the major factor in loss of life in aircraft accidents. While much attention has been devoted to this subject by the NFPA Committee on Aviation and Airport Fire Protection and the many organizations represented in this cooperative project, current fire experience seems to show that the problem instead of getting better is actually becoming worse. At one time it was supposed that the introduction of jet propulsion with a higher flashpoint fuel would reduce the fire problem, but this is apparently not to be the case. There appears no easy answer and the problem presents a serious challenge to the entire aviation industry as well as to fire authorities.

The Wrong Extinguisher

Any extinguisher is a wrong extinguisher when used improperly on a type of fire for which it is not suited, if made the excuse for neglect of other fire safety measures, and above all if occupants of burning buildings fail to call the fire department because of an exaggerated faith in the miraculous powers of an extinguisher. The first approach to this problem is obviously public education, emphasis upon the importance of purchasing standard approved extinguishers rather than small, cheap gadgets which are called extinguishers but which have very limited value, upon proper maintenance, and particularly upon the fact that the first thing to do in case of fire is to call the fire department, even though you do have an extinguisher in your home.

There is still no all-purpose extinguisher for all classes of fires. Confusion continues, lives are lost, and much property is destroyed, because laymen try to use a Class B extinguisher on a Class A fire, for example. There have been groping attempts to meet this problem by using different color designations for different classes of extinguishers, but at best such efforts can be successful only in situations such as industrial plants where all the occupants of the building can be given instruction as to the significance of the colors.

* * * * *

This catalog of fire problems could be continued to great lengths, but the items cited above are perhaps sufficient to call attention to the kind of problems that confront us in 1952. We cannot expect to solve them all during the year. They are, however, matters which we should all think about and if all the members of the National Fire Protection Association, individually and collectively, will consider these problems and do their part towards meeting them we can feel certain that by the end of the year at least some progress will have been made.

NFPA Standards A Bar Against Communism

By Thomas M. Torrey
Chairman, NFPA Committee on Marine Fire Protection

During the first two and one-half years of World War II, I had a chance to watch first-hand Government bureaucracy in operation when I was loaned by the Insurance Company of North America to help the War Shipping Administration to set up its war risk insurance office. There were some of the finest minds in the maritime industry in that organization beating their brains out trying to do a real job, and I am here to tell you they did it in spite of the most appalling internecine wrangling, petty back-biting, useless red tape and political greed imaginable! I came away from that experience with the firm conviction that short of actual war, government interference in any commercial enterprise can only lead to stultification and ultimately to socialization, and then the final step — communism.

We have been for twenty years in an era of increasing government encroachment on private enterprise. This interference cannot always be avoided, but its effect can be lessened, if not ultimately made unnecessary in certain fields, by self-regulation of the enlightened kind.

Self Regulation Best

The theory of self-regulation is nothing new — it boils down in last analysis to nothing more than self-discipline among individuals. The need for governmental regulation comes when human relations fail or, in another sense, company, corporate or industry relations fail either among each other or, more importantly, fail in their responsibilities to the individual citizen. When you step into the international field, which the marine industry touches daily, the problem is so complex that perhaps some interjection of government regulation is necessary — different ethics, different standards of living all play a part.

Obviously some government regulation is necessary, otherwise why the need of our Constitution or Bill of Rights? The essential factor is to keep government at an irreducible minimum and allow the fullest play to individual enterprise. I am convinced that the most efficacious means of doing this is so to regulate yourself — that is, your industry — that anything short of arbitrary action by government is largely unnecessary.

Let us admit for the moment that the need for discipline or self-regulation is wise. Such a course of action does not imply by any means that you have to be afraid of your shadow. There are plenty of examples where just such practices have been followed successfully for years. I can think of several examples — the flammable oil carriers in their relations with the Coast Guard — the port security set-up during the last war — the steamship lines that year after year build and maintain their ships on standards in excess of the so-called minimum standards.

It is unfortunate that every time there is a disaster by fire at sea involving loss of human life a great hue and cry is set up

Note: This article is a condensation of a talk by Mr. Torrey before the Portland, Oregon NFPA Regional Meeting, October 24-25, 1951.

which results in needlessly burdensome requirements being imposed on owners and operators. How much better it would be to have all this taken care of in advance — within the family so to speak—rather than devising better means of locking the barn door after the horse is stolen.

NFPA Fits Into Picture

All the talent and know-how needed to solve its present and future problems lies within the maritime industry. It is our hope that the NFPA Marine Committee will form the focal point for a concerted drive to develop and recommend improved methods, plans and all that goes toward making the incidence of fire as close to zero as human or mechanical failure will permit, *but* we want these to be developments within the industry for the industry and the people they serve, because there is still no substitute for individual initiative.

This hope is not impossible of accomplishment. In fact, to a large extent the recommended practices of the old Marine Section of NFPA, which our committee has succeeded, have been adopted as integral parts of current Federal legislation. Bedeviled as the marine industry is by Federal red tape, how much better off they are because there was in existence a source of sound and tested practices to serve as a guide when these laws were passed.

Unfortunately, when so much of the past labors of the old Marine Section were absorbed by the Government a period of inertia set in, and except for the Gas Hazards Committee, which is a joint committee of NFPA and the American Bureau of Shipping, there was little real activity. Also in a large measure the lack of constructive work was due to the disruption of the war years.

Three years ago we set up our present committee for four purposes: First, to survey existing recommendations and eliminate duplication where suitable regulations were issued by official or quasi-governmental organizations. Second, to bring the remaining standards up-to-date in the light of the rapid technological developments during the war years. Third, to develop new recommended practices and standards for related branches of the maritime industry, thereby providing a real service and also filling certain obvious voids which might go by default under the administration of some empire-building bureaucrat. And fourth, and by far the most important, to devise new and better means to prevent fire and its ensuing toll of lives and property, or, failing that, to control and confine its destructive powers.

We have made fair progress. The recent publication by NFPA of its several standards for marine fire protection is good evidence of this. There is much more still to be done. Our Marine Committee still has a large amount of work to do, but we intend to do that work by and with the cooperation of the industry for whom it is designed.

Fire Safety in Tank Truck Design

By T. A. Burress, Manager, Tank Division
The Heil Company

The daily delivery of gasoline and fuel oil to the metropolitan consuming areas today is just as indispensable as the home delivery of milk. Because of the growing demand, petroleum transportation over the highway has grown tremendously over the past few years. In the four-year period from 1945 to 1949, over-the-road movement of petroleum has jumped from nineteen million to thirty-seven million tons, an increase of 92%. The problem, therefore, is not whether petroleum shall or shall not be transported over city streets, but how to do it with reasonable safety.

To achieve reasonable fire safety, the National Fire Protection Association has had standards for tank trucks since 1929. The current edition (adopted in 1948, reprinted in 1950) is designated: "Recommended Regulatory Standard for Tank Vehicles for Flammable Liquids" (NFPA No. 385) * and is widely used by the tank manufacturers for guidance in meeting reasonable safety for this equipment. How this is being done in practice is illustrated in this article.

The design and maintenance of the tank vehicle itself is only one part of the overall problem. The traffic accident hazard, common to all highway transportation, is a matter of major concern to tank truck operators. The actual accident record of tank trucks is better than that of trucks in general, presumably due to better equipment, better maintenance and greater care in operation. Thanks to good design and maintenance, only a very small part of the total number of accidents involve fire to any major degree.

Materials Used

The NFPA standard is very specific in the authorized types of materials that may be used for cargo tanks, head, bulkhead and baffle sheets. Paragraph 212 states: "the minimum thicknesses of tank sheets shall be limited by the volume capacity of the tank expressed in terms of gallons per inch of length; and by the distance between bulkheads, baffles or other shell stiffeners, as well as by the radius of shell curvature in case of shell sheets." The standard then specifies minimum thickness of shell sheets, head, bulkhead and baffles whether made of hot rolled tank steel, of aluminum or of low alloy low carbon (high tensile) steel.

Photo No. 1 shows a cut-away view of a modern transport tank with deep dished single and double bulkheads and baffles, properly spaced and reinforced to distribute the load and stresses.

"Every cargo tank, and every compartment over 90 inches in length, shall be provided with baffles" according to the NFPA recommendations. The number of baffles "shall be such that the linear distance between any two adjacent baffles, or between any tank head or bulkhead and baffles nearest it, shall in no case exceed 60 inches." The baffles, shown in the cut-away view, are perforated transverse partitions to break the force of surging liquids

*Copies available from NFPA Executive Office (25 cents each, discount for quantity). See also National Fire Codes, Vol. I, 1951.

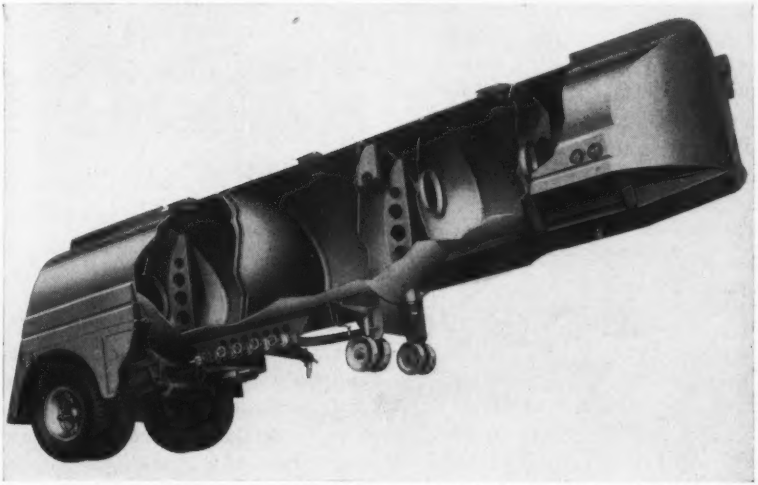


Photo No. 1. Cut-away view of typical transport tank showing single and double bulkheads and baffles.

in a partially filled tank and also provide additional stiffeners to make the tank a self-supporting, beam-like structure.

NFPA Standard No. 385 also provides that "cargo tanks with compartments carrying flammable liquids of different classes shall be provided with an air space between compartments and this air space shall be equipped and maintained with drainage facilities operative at all times." The cut-away view shows a double bulkhead with such an air space which has a drain hole at the bottom, a vent hole at top.

Compartmentation

There have been many attempts to regulate the capacity of tank trucks. After the Chicago street car disaster,* various agencies proposed restrictive legislation on tank truck capacity, the figure most usually advanced being 3,000 gallons.

The NFPA Committee on Flammable Liquids, in developing the Association standards, did not include any overall limit of capacity. Mr. Robert S. Moulton, NFPA Technical Secretary,* in writing on this problem, has explained the basis of the committee's action; that small capacities mean more trucks, greater exposure to accidents, and more trips per vehicle. Furthermore, the extent of hazard does not depend directly on the quantity of gasoline. A hundred gallons of gasoline spilled on a city street and ignited may have fatal results for all those in its direct path; a thousand gallons is not likely to cause ten times the loss, and ten thousand gallons, while obviously worse than a hundred, is clearly not one hundred times as dangerous.

Current NFPA recommendations call for compartmentation, not to exceed 1200 gallons per compartment (with 10% tolerance), for trucks used in the distribution of over 1500 gallons of "Class A"† flammable liquids to service stations and other premises to which the public is invited.

*See NFPA "Fire News," June 1950.

†Class "A" liquids have flash point below 70°F and a vapor pressure not exceeding 40 pounds.

Bulkheads or compartments are not required in any cargo tank, regardless of total capacity, "which when loaded and transporting its cargo over streets and highways will contain not less than 80% of the total tank capacity and will discharge its entire contents at one unloading point, provided such cargo tank is not used for the delivery of flammable liquids to service stations or other premises to which the public is invited."

Cargo Tank Testing

As for every fabricated container designed to hold liquids or gases subject to pressure increases under various conditions of usage, tests are necessary to determine that all joints are leakproof and capable of withstanding predesignated pressures. The NFPA Standard calls for tests of every cargo tank by "a minimum air or hydrostatic pressure of three pounds per square inch applied to each compartment, or to the whole tank if it be not divided into compartments." This pressure test must be maintained for at least five minutes during which joints are inspected for leakage.

Many manufacturers go beyond these conventional tests. Photo No. 2 shows equipment used by The Heil Company for recording stresses placed on the tank under various loads and conditions of service while Photo No. 3 shows a tank truck undergoing field trials.

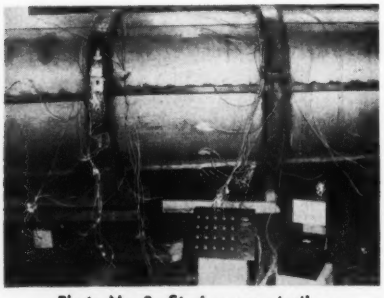


Photo No. 2. Strain gauge testing.

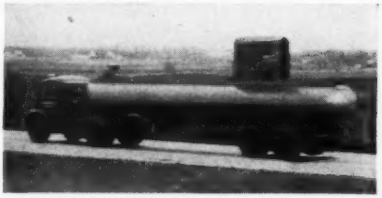


Photo No. 3. Road trials. Stress gauges are mounted in enclosure on top of tank.

Vents and Emergency Controls

Structural strength, alone, is not sufficient. We must be able to load, unload and safely take care of both the pressures and the vacuum conditions created in the tanks under both normal and abnormal conditions.

Manholes, used for inlets for filling and access for cleaning, are also provided and designed to include a vent which allows an influx of air to relieve the vacuum caused in unloading and to relieve pressure caused by expansion of the product on a hot day or in case of fire. The typical manhole cover shown in Photo No. 4 has a built-in pressure and vacuum relief vent illustrated in detail in Photo No. 5.

The NFPA recommendations on vents are detailed in paragraph 281 of Pamphlet No. 385. In this reference, it states that if "the emergency venting facility operates in response to elevated temperatures, the critical temperature for such operation shall not exceed 200°F. Photo No. 6 shows a typical fusible plug (160°F solder) designed to allow expanding gas to escape as vapor without danger of tank explosion. It incorporates, also, a "fire screen" at the base of the plug to guard against flame entry into the tank as the pressure subsides. The capacity and number of plugs is determined by the sizes of the compartments.

"Each cargo tank or compartment used for transportation of Class 'A' flammable

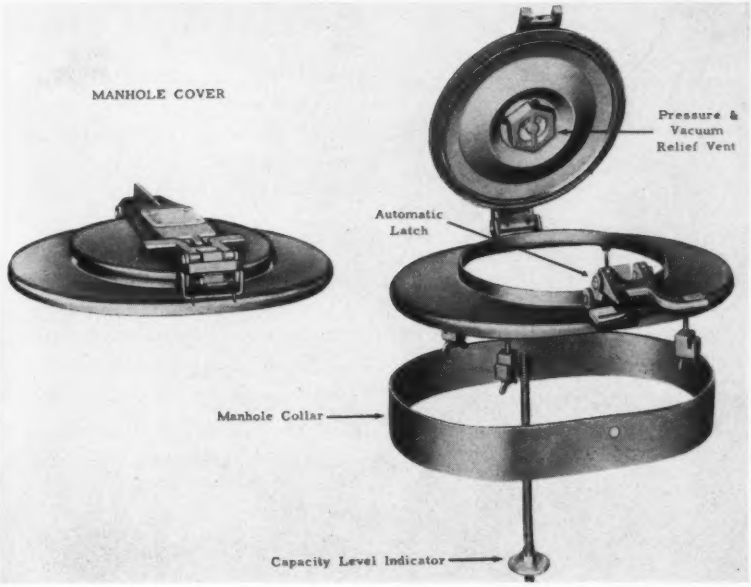


Photo No. 4. Typical manhole provides inlets for filling and access for cleaning plus pressure and vacuum relief vent.

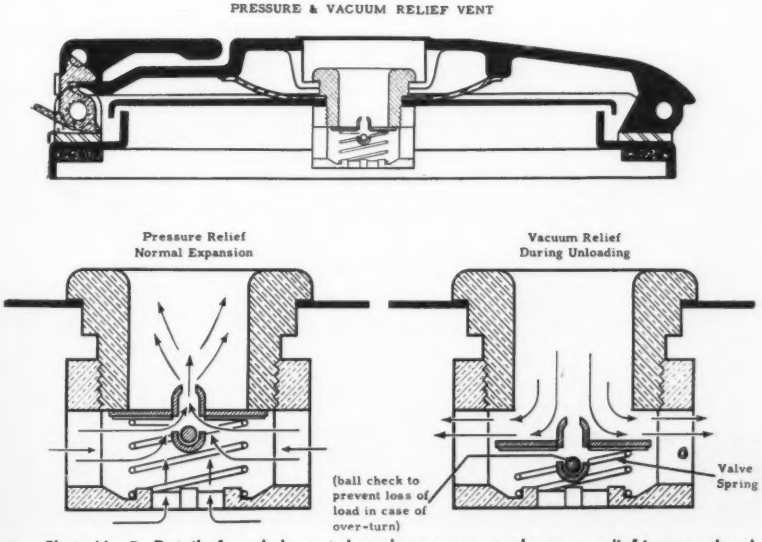


Photo No. 5. Detail of manhole vent shows how pressure and vacuum relief is secured and how spillage is prevented.

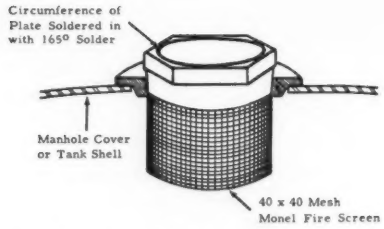


Photo No. 6. Fusible plug and "fire screen" installed in each tank compartment.

liquids," says NFPA Standard 385, par. 301, "shall be equipped with a reliable and efficient shut-off valve located inside the shell in the outlet; or in the sump when it is an integral part of the shell; and so designed that the valve must be kept closed except during loading and unloading operations." Par. 304 goes on to say "in every case there shall be provided, between the shut-off valve seat and discharge faucet, a shear section which will break under strain unless the discharge piping is so arranged as to afford the same protection and leave the shut-off valve seat intact." These design features are illustrated in Photo No. 7.

The purpose of this construction is to keep the product within the compartments and out of the pipe lines, except during unloading, and to prevent the cargo from

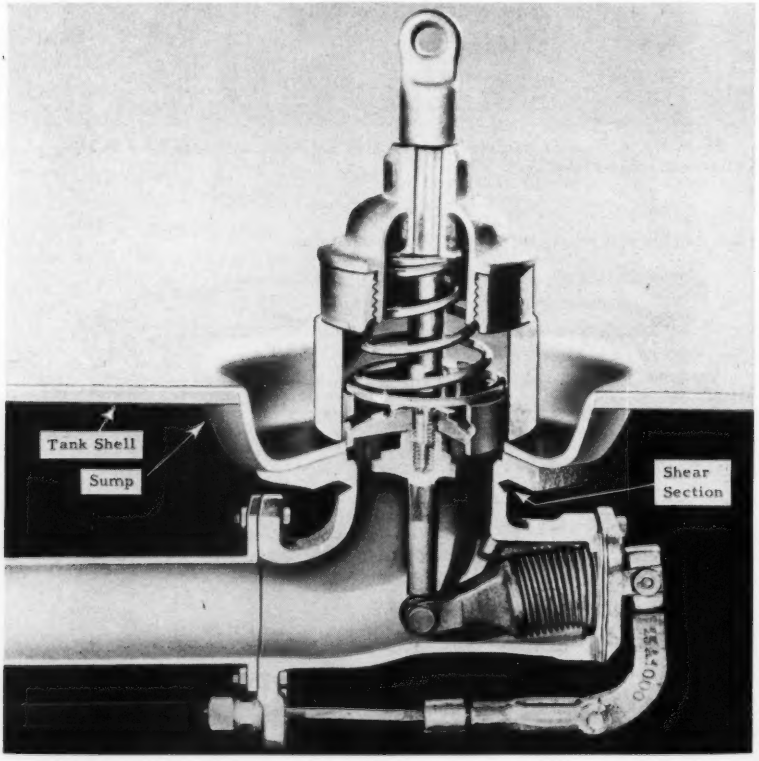


Photo No. 7. Shut-off valve located inside tank shell with shear section to leave valve shut if discharge faucet breaks.

spilling or discharging on the street in event of undue stress to the pipe lines.

There is always the chance that an accident or fire might occur during delivery operations and, for that reason, NFPA Standard No. 385, asks, in par. 302, for a secondary control on the valve operating mechanism remote from the fill openings and discharge faucets. In practice, this remote control is usually located at the front of the tank on the opposite side from the discharge manifold. The so called "Heil-Warren" air operated emergency valve system (see Photo No. 8) is one type found on petroleum tank trucks with which fire fighters should be familiar. Other types of valves may be mechanically or hydraulically operated but all function essentially alike.

In addition to these provisions, "the control mechanism shall be provided with a fusible section which will cause valves to close automatically in case of fire."

Protection Against Intermixing

The provisions of the NFPA Standard on intermixing of flammable liquids are usually met in practice by having duplicate pipe lines, separate manifolds, meters and pumps. Photo No. 9 shows a spilt manifold system while No. 10 shows two meter installations on a truck designed to carry two different petroleum products. This avoids the necessity of flushing meters to eliminate Class "A" flammable liquids if the same meter had to be used to dispense Class "B." Photo No. 11 shows a bottom view of a typical transport tank illustrating the arrangement of the emergency valves, pipe lines and manifolds.

Other Safeguards

Other major design safeguards in the NFPA Standard No. 385 include:

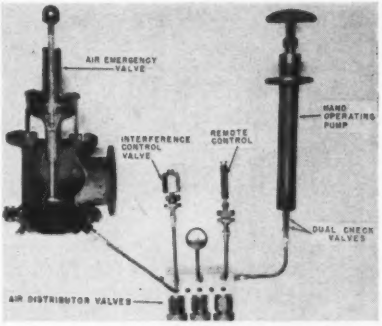


Photo No. 8. Typical air operated emergency valve system.

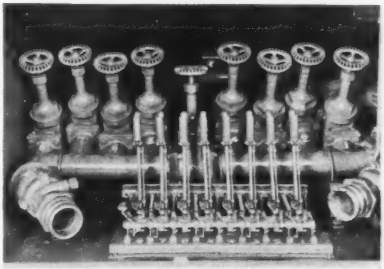


Photo No. 9. Split manifold to prevent intermixing.

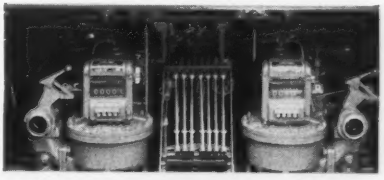


Photo No. 10. Twin meter installation for dual purpose transports.

(1) Bonding of cargo tanks and the vehicle chassis to assure that there can be no difference of static potential on adjacent metallic surfaces. Provision is also made for the bonding of the vehicle and the fill pipe prior to each filling of the tank. The use of "drag chains," previously required, has been eliminated as they are now considered both inefficient and unnecessary.

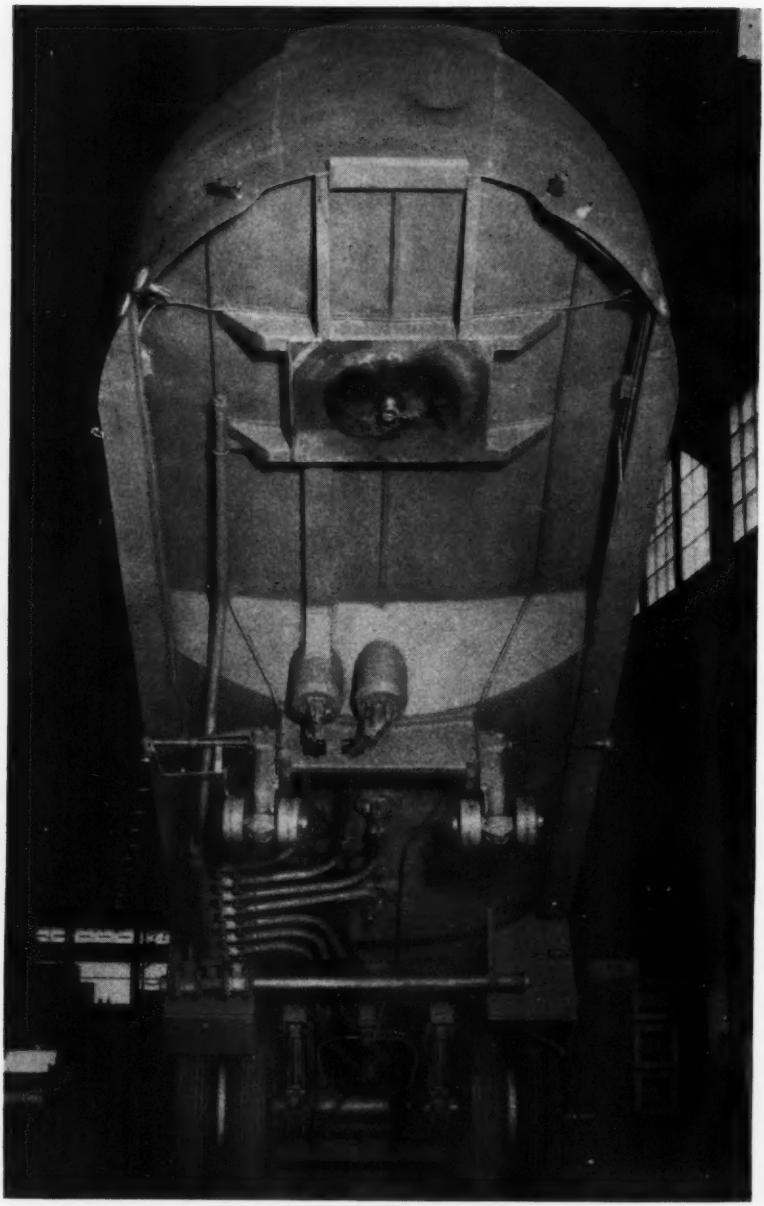


Photo No. 11. Bottom view of a "semi" showing emergency valves, pipe lines and manifolds.

(2) Protection of draw-off valves or faucets projecting beyond the frame at the rear of the tank vehicle by bumpers and similar means.

(3) Proper construction of vehicle fuel tanks, fuel-feed systems, exhaust systems and lighting circuits.

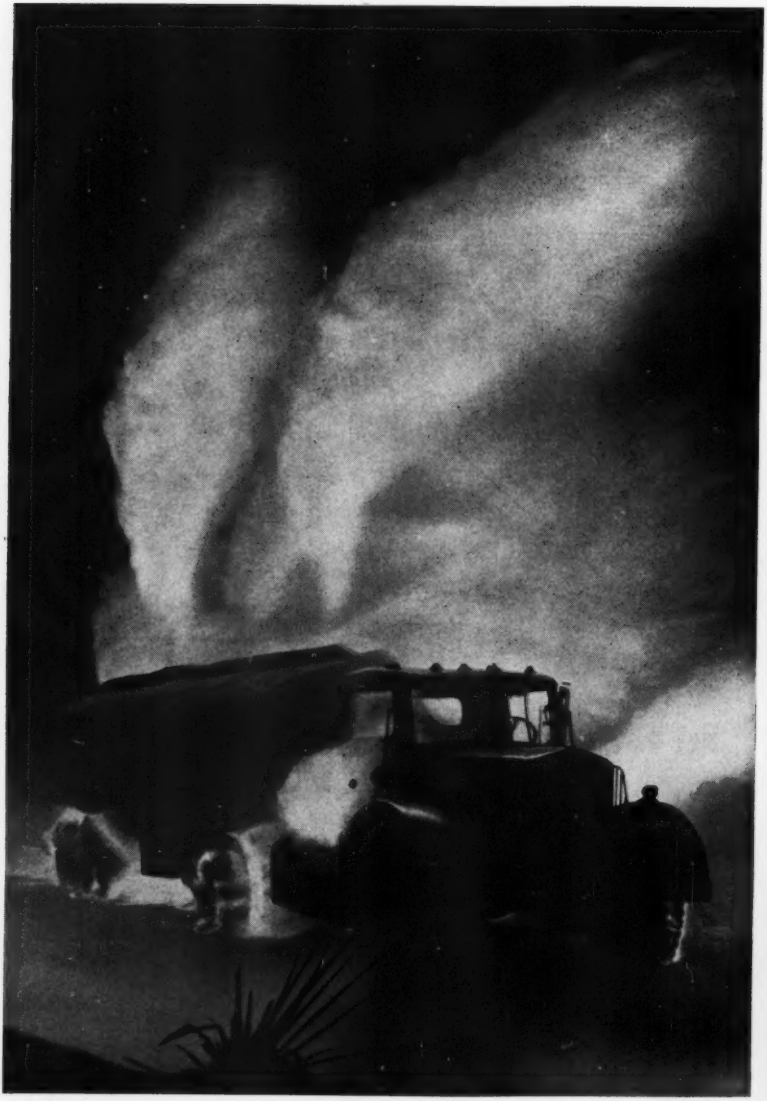
(4) Secure attachment of full and semi-trailers to their tractors and adequate provisions for controlling and braking of such trailers.

(5) Recommendations on the construction and arrangement of auxiliary internal combustion engines and auxiliary electric generators and motors.

The provision of suitable fire extinguishers and recommendations on the proper operation of tank trucks are also included in NFPA No. 385.

Other Factors

Reputable manufacturers of petroleum tank vehicles are doing their utmost to meet these design safety requirements in the interest of the general public. Maintenance of the tankers is the responsibility of fleet operators and while the safety record is good, constant attention must be given to this phase of the problem as well as to the progressive education of drivers in safe driving habits. Much can be done by fire officials working with police and the trucking industry in routing trucks through cities on streets having low accident potential and low fire exposure hazard. In working out such solutions, however, safety officials should be ever mindful of the needs of the community for petroleum distribution so that their recommendations will be practical and workable and in the public's interest. Fire officials would also do well to instruct their personnel in the design safeguards provided on tank vehicles for flammable liquids and it is principally for this reason that this article has been prepared for the NFPA *Quarterly*.



Acme Photo

Leak at bulkhead between compartments of this tank truck caused this fire in Old Augusta, Ind. on Mar. 31, 1949. Fire spread to four dwellings. Improper vehicle maintenance is shown by this fire record to be the principal cause of tank truck fires on U. S. highways.

Gasoline Tank Truck Fire Record

The foregoing article describes the fire safety designs of the modern, properly constructed petroleum tank truck. As everyone knows, fire accidents do occur. This brief gasoline tank truck fire record prepared from a representative sample of cases in NFPA files for the period 1946-1951 is offered to illustrate the principal factors.

Improper Vehicle Maintenance

Our analysis here includes 40 cases. Ten of the 40 accidents, the greatest proportion, may be basically assigned to improper vehicle maintenance. Perhaps included in this broad category are some design weaknesses which cannot be positively identified as such with the information available to the NFPA. Air brake failures, trailer breakaways, broken axles, etc. may reflect improper design of such features but are assigned to poor maintenance on the assumption that construction was originally adequate. None of the trucks sustaining such experience was new when the accidents occurred and there is no pattern of failures to indicate specific recurrent weaknesses.

No. 1. June 24, 1948, New York, N. Y., Tank Semi-Trailer: Fire in pump compartment during fueling of aircraft caused by separation of a slip type compression coupling in a three-inch gasoline line below the right meter. Capacity of tank, 4,000 gallons. The fire was controlled by the airport fire department using fog foam and by airport ramp personnel using carbon dioxide.

No. 2. July 7, 1948, Little Rock, Ark., Tank Truck: Explosion in pump compartment during inspection. Gasoline vapors accumulated in compartment from leaks around pump packings. Capacity of tank, 2,000 gallons. Ignition source believed exhaust spark as the exhaust vented inside the compartment. Fire extinguished by CO_2 extinguishers.

No. 3. March 31, 1949, Old Augusta, Ind., Tank Full-Trailer: Driver discovered truck burning while going down residential street at 30 MPH. Apparent cause was leak at bulkhead between compartments with ignition source either static spark or exhaust from engine. Fire spread to four houses and telephone wires. 5,000 gallons of gasoline involved. Driver could not control with hand extinguishers. Local fire department could not extinguish. Loss estimated at $25,600.

No. 4. April 13, 1949, Near Castaic, Calif., Tank Semi-Trailer: Brake failure at the top of a five-mile grade resulted in loss of driver control of a 4,000-gallon tank truck which crashed and burned. No fire fighting due to location. 2 persons killed.

No. 5. Oct. 26, 1949. Oakland, Illinois, Tank Full-Trailer: Vehicle proceeding at 30 MPH when driver felt a sudden jerk. Looking back he saw full-trailer had gone over on its side and was burning.

No. 6. June 1, 1950. Ypsilanti, Michigan, Tank Semi- and Full-Trailer: Fire originated in rear trailer when right axle broke and trailer tipped on side. Ignition presumed from sparks caused by scraping on pavement. About 2,700 gallons of the 4,200 gallons in the rear trailer were consumed by the fire but the semi-trailer with 4,500 gallons aboard was not involved despite serious fire exposure. Flames damaged exposed building and burning fuel entered sewer catch basin. Fire department protected exposures and cooled tank with water fog and solid hose streams. Loss estimated at $10,000.

No. 7. June 15, 1950. Northlake, Illinois, Tank Full-Trailer (Double): Rear of two trailers broke loose and tipped over. Gasoline released from three-inch slit on right side of 4,000-gallon tank caused by impact with concrete curb. Firemen washed unburned gasoline down sewer not realizing sewer emptied into a creek which

Acme Photo

Driver was going 30 MPH down highway in Oakland, Ill., Oct. 26, 1949 when he felt a sudden jerk and the full trailer overturned.

Acme Photo

Rear axle failure in city streets of Ypsilanti, Mich. caused rear trailer to tip-over. While 2,700 gallons of gasoline burned, semi-trailer was not involved.

Maurice Herbert-Newburg-Beacon News

U. S. Air Force crash crew responded to this tank truck fire near Newburg, N. Y., on June 29, 1950 and extinguished fire with water fog.

John S. Savage

Air brake failure caused tank truck to crash into building at bottom of down grade in Omaha, Neb., May 31, 1951. Tractor fuel tank ruptured at impact and fire spread to gasoline in two compartments of trailer, also ruptured by collision.

Acme Photo

Another air brake failure caused this tip-over in Excelsior, Minn., on Aug. 16, 1951.

passed under State Highway one mile from accident site. Fire started at bridge (presumably from a lighted match thrown into the creek) and flashed along creek for 1 mile. Firemen used high pressure water fog to prevent spread of fire to exposed properties. Loss estimated at $30,000.

No. 8. June 29, 1950. Newburg, N. Y., Tank Full-Trailer: Fire originated at tractor fuel tank (95-gallon capacity) and first involved cab. Flames spread to trailer (6,000-gallon capacity) and approximately 500 gallons were consumed by resultant fire. Fire extinguished by airport crash trucks using high pressure water fog from two turrets and five hand lines of crash truck. Loss estimated at $10,590.

No. 9. May 31, 1951. Omaha, Nebraska, Tank Semi-Trailer: Truck going down grade to a "T" intersection sustained air brake failure and crashed into building. Fire resulted as gasoline spilled from ruptured tractor fuel tank and spread to 2,700 gallons of gasoline in two compartments of the trailer tank which were fractured at the impact. Driver was killed by the ensuing fire. Fire spread to building and parked autos in vicinity. City fire department used foam on tank-truck with water fog and straight streams on buildings and 17 vehicles. Loss estimated at $173,000.

No. 10. Aug. 16, 1951. Excelsior, Minn., Tank Full-Trailer: Driver unable to brake tractor-trailer on slight down-grade curve and vehicle turned over. Fire started in tractor and spread to gasoline released from 7,000-gallon capacity trailer. Driver may have been killed by impact but body consumed by fire. Gasoline spilled down grade to and through a culvert. Fire department traveled 3 miles to scene and used foam to extinguish fire.

Driver Operational Error

Driver operational error was responsible for nine of the accidents. Compared with the exposure factor, the fact that only nine of the 40 accidents, picked at random, were driver errors would indicate a rather superior degree of driver training by petroleum haulers, yet it does, at the same time, emphasize the importance of this phase of the tank truck safety problem.

No. 11. July 21, 1946. Oconomowoc, Wisc., Tank Semi-Trailer: Truck seen weaving down highway, hit curb and rolled over to an upside-down position in the center of the street. About 4,200 gallons of gasoline spilled and burned over 350 feet of highway. Driver had been refused license due to epileptic affliction and was operating truck illegally. Fire department confined spread of fire to telephone poles, protecting exposed houses and railroad box cars.

No. 12. Nov. 29, 1946. Devil's Slide, Utah, Tank Full-Trailer: Tank trailer jack-knifed in railroad underpass, caught fire and caused extensive damage to steel work and railroad rails, halting rail travel over the main line of the Union Pacific for 10-12 hours. Tank capacity of 6,400 gallons burned. Loss estimated at $60,000.

No. 13. Feb. 6, 1947. Washougal, Wash., Tank Semi-Trailer and Tank Full-Trailer: A triple collision involving two tank trucks and a hay wagon in the middle of a 220-foot unprotected steel highway bridge caused a fire which ultimately collapsed the bridge. A total of 9,000 gallons of gasoline burned. No fire fighting due to location of fire. Loss estimated at $276,000.

No. 14. Aug. 5, 1947. Waxahachie, Tex., Tank Semi-Trailer: Tank truck rounded curve and pulled over on left side of highway striking head-on a 1½-ton truck carrying 18 persons. Saddle tank of tractor ruptured by impact and fire spread to 4,000-gallon tank trailer. Nineteen persons killed; loss set at $11,700.

No. 15. Sept., 9, 1947. Mountainside, N. J., Tank Full-Trailer: Trailer (4,500-gallon capacity) broke away from the tractor when the truck mounted the curb on a curve. The trailer struck a middle-of-the-highway island and ruptured. Gasoline released flowed down gutters on both sides of the street in flames and fire caused extensive damage to a service station and three houses. Four fire departments fought the fire with water fog and foam, extinguishing the blaze in 1½ hours. Loss estimated at $30,000.

No. 16. June 25, 1948. Edwardsville, Ill., Tank Truck: Overturn of gasoline tank truck going through village resulted in fire which ignited four exposed dwellings. Truck driver trapped in cab and fatally burned. Estimated 8,000 gallons of gasoline involved in fire. Fire department could only cool tanks, extinguish fires in

Smith Studio

Unlicensed driver subject to epileptic fits upset this semi-trailer in Oconomowoc, Wisc., July 21, 1946.

Press Association

Tank truck driver swerved without obvious reason to left-hand side of highway near Waxahachie, Tex., Aug. 5, 1947, striking a 1½-ton truck carrying 18 workers, all of whom were killed.

Acme Photo

Driver apparently lost control on curve. Trailer (4,500-gal. capacity) upset and ruptured on island in center of street at Mountainside, N. J., Sept., 7, 1947.

Acme Photo

Speeding tank truck upset on highway near Barrington Twp., Ill., Oct. 9, 1950, as driver misjudged intentions of another driver preparing to turn left from the opposite lane.

Acme Photo

Failure to control this semi-trailer on a curve resulted in this fire in the mountains near Bloomingburg, N. Y., last June 2.

Wide World Photos

This is the remains of the tanker involved in the tragic Chicago trolley car-tank truck accident on May 25, 1950, which was fatal to 33 persons and caused injuries to 50 others. Only gasoline in the 40-gallon tractor tank and 4,000 gallons in the first trailer (damaged at the impact) were involved, the contents of the full rear trailer not being ignited despite serious fire exposure.

dwellings and flush gasoline into street catch basins. Loss estimated at $2,550.

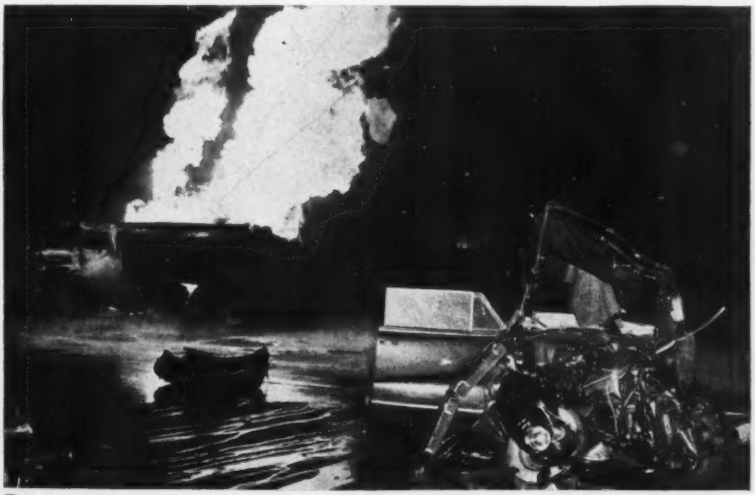
No. 17. July 14, 1949. Near Wheelersburg, Ohio, Tank Full-Trailer: At 1:45 a.m. the 5,800-gallon tank truck crashed into a utility pole on Route 52. By the time the nearest fire department could reach the scene the truck was heavily involved. No spillage occurred. About 3,300 gallons of the total 5,800 were consumed by the fire. Hose streams turned to steam on the hot metal tank but fire was eventually extinguished. The driver was killed and the loss estimated at $8,000.

No. 18. Oct. 9, 1950. Barrington Twp., Ill., Tank Semi-Trailer: The driver of a 6,000-gallon tank truck tanker traveling at excessive speed misjudged the intentions of a small truck which had stopped at an intersection before making a left turn. The tank truck driver attempted to pass the smaller truck on the wrong side but because of his speed was unable to do so and crashed head-on into the stopped truck. The trailer overrode the tractor, puncturing the forward gasoline compartment and overturned. 6,000 gallons of gasoline made a pyre out of both trucks, cremating the drivers of each. Firefighters had no water to fight the fire.

No. 19. June 2, 1951. Near Bloomingburg, N. Y., Tank Semi-Trailer: Truck jack-knifed and caught fire while rounding a curve on mountainous Route 17. No fire fighting due to location.

Other Drivers

Other drivers, that "other fellow" on the road, were clearly responsible for 7 of the accidents. What the transport tank manufacturers and operators can do about such cases is not clear. There is not much defense against speeding vehicles or trolley cars crashing into and rupturing tanks except that which can be accomplished by the material strength of the tank shell and proper tank vent protection against internal explosion. There is, of course, a practical limit to the shock resistance of structural members. It is significant that in this entire record there were only two tank explosions (one with tank practically empty) despite severe fire exposure to the vehicles involved in the majority of cases. This fact indicates design adequacy.



Wide World Photos

In Hammond, Ind., on Sept. 2, 1948, a speeding passenger car crashed this gasoline semi-trailer. Fire department extinguished fire with CO_2 after cooling tank with hose streams.

Wide World Photos

Tank truck driver forced off road by another car crashed into stone wall in Adrian, Mich., June 1, 1950. Fire originated in tractor tank, spread to fuel leaking from trailer domes.

Wide World Photos

Another driver failed to stop at a highway intersection and collided with this tanker in Tracy, Calif., Oct. 17, 1951.

No. 20. Sept. 2, 1948. Hammond, Ind., Tank Semi-Trailer: A speeding passenger car smashed into a gasoline tank truck, causing a serious fire involving about 2,000 gallons of gasoline. The fire department cooled tank with water and extinguished the fire with 2 tons of low-pressure carbon dioxide available on special fire rig.

No. 21. Sept. 16, 1949. Chantilly, Va., Tank Full-Trailer: Head-on collision between gasoline tractor-trailer (5,500 gallons capacity) and tractor-trailer hauling empty oxygen cylinders on narrow bridge. Fire spread to two other automobiles. Drivers of both trucks trapped and burned to death in cab. Five fire trucks from three volunteer fire departments responded and extinguished the fire in two hours. Loss estimated at $30,000.

No. 22. Jan 27, 1950. Cambridge, Mass., Tank Semi-Trailer: Speeding passenger car (being chased by police) smashed into trailer, causing tank rupture. 250 gallons of the 2,500-gallon tank burned, the fire occurring at impact. Fire department used water fog with excellent results. Three were killed and loss estimated at $4,500.

No. 23. May 25, 1950. Chicago, Ill., Tank Full-Trailer: Trolley car struck tank truck, rupturing fuel supply tank of tractor (40-gallon capacity). Rear of tractor frame ripped open the bottom of the semi-trailer, releasing 4,000 gallons of gasoline. Second bottom not involved despite serious fire exposure. Thirty-two passengers were trapped in trolley and died in ensuing fire as exits jammed. Fifty others were injured. Fire spread to buildings and automobiles along street. (See NFPA *Fire News*, June 1950 for complete details.)

No. 24. June 1, 1950. Adrian, Michigan, Tractor Semi-Trailer: Truck struck stone wall after attempting to avoid hitting car and house. Believe fuel tanks on tractor ruptured and caused fire which spread to fuel which leaked from tank dome covers. About 2,500 gallons of 4,100 gallons aboard consumed in flames. Fire department controlled blaze after spilled fuel had burned out. One person killed and damage estimated at $14,600.

No. 25. Sept., 7, 1950. Kankakee, Ill., Tank Full-Trailer (Double): Truck proceeding down city street when tanker overturned and fire resulted after it struck a car which had turned in front of the truck. Fire extended 300 feet along street and involved a foundry building, a gasoline station and two parked cars. Fire fighters used fog and foam to control blaze and restricted damage effectively. Loss estimated at $30,000.

No. 26. Oct. 17, 1951. Tracy, Calif., Tank Full-Trailer (Double): Tank truck in collision with another truck at an intersection when the driver of the latter failed to stop at a stop sign before entering a main highway. One driver was killed.

Railroad Grade Crossings

Railroad grade crossings were responsible for five of the accidents reported herein. Whether the train hit the truck or the truck the train is an academic question insofar as fire experience is concerned but the disastrous effects of such accidents makes it very important that petroleum haulers exercise firm control over drivers requiring them to stop at all railroad crossings and to actually LOOK and LISTEN. There have been cases where the driver stopped, perfunctorily, but proceeded without the necessary caution.

No. 27. Feb. 4, 1947. Kingsburg, Calif., Tank Full-Trailer: The driver of the fuel truck failed to come to a stop at a grade crossing and a steam locomotive traveling 43 MPH struck the 7,100-gallon trailer, showering the streamlined passenger cars with gasoline. 4 persons were killed and 115 passengers and 14 train service employees injured. Losses estimated at $225,000, excluding personal liability.

No. 28. Sept. 20, 1949. Port Carbon, Pa., Tank Semi-Trailer: Collision at grade crossing between 4,500-gallon tank truck and train. Fire spread to railroad baggage car, a near-by garage and a parked auto. The truck driver was fatally burned and four others received non-fatal but serious burns. Four fire companies responded to the alarm but it took 2 hours to control the blaze.

No. 29. May 24, 1950. Albany, N. Y., Tank Full-Trailer: The truck was struck by a railroad switch engine at the rear compartment, crushing the tank and causing a spill. Fire did not occur until about 10 minutes after the fire department

Press Association, Inc.

One of the worst railroad crossing accidents of all time. Four were killed and 129 injured when fuel tank truck failed to stop at crossing in Kingsburg, Calif., Feb. 4, 1947.

In Albany, N. Y., on May 24, 1950, a switch engine hit a 5,200-gallon full-trailer.

Wide World Photos

The Longview, Tex. fire department used high and low pressure fog to confine this grade crossing accident on Oct. 30, 1950. Crossing accidents, such as this, emphasize the importance of driver training. There is rarely a valid excuse for such collisions. Fire frequency is heightened by the presence of multiple ignition sources.

arrived when the vapors ignited at a stove in a railroad shanty. About 2,000 of the 5,700 gallons in the tank truck were consumed in the ensuing fire. The fire was fought with water fog and foam.

No. 30. Oct. 30, 1950. Longview, Texas, Tank Semi-Trailer: Locomotive and tank truck collided on grade crossing. Train hit about half way back on tank. Fire originated in fuel spill, ignition source possibly locomotive fire box. 5,200 gallons in tank consumed by fire. Fire department used high and low pressure fog to retain fire to small area. Loss estimated at $4,000.

No. 31. Nov. 30, 1951. Near Kalamazoo, Mich., Tank Full-Trailer (Double): A tank truck stopped at a railroad crossing then proceeded across tracks. A diesel powered passenger train collided with rear trailer and ruptured front tank. Train traveled through flames. 7,790 gallons of gasoline in tank truck burned. Fire department used water fog and secured good results on spill and railroad equipment but not on tank truck till gasoline nearly consumed. Loss estimated at $60,900.

Loading and Unloading

Loading and unloading operations introduce hazards incident to the handling of flammable liquids necessitating specialized fire safety precautions. Constant vigilance is needed to guard against leaks in valves, pumps or lines. Steady attention must be given to proper bonding to control static charges. Because the release of flammable vapors to the atmosphere is practically unavoidable, each operation should be proceeded by a check of other possible ignition sources (*i.e.*, open flames, electrical arcs, etc.). It takes education and reeducation, training and refresher courses and, in addition, a constant battle must be waged against the contempt bred of familiarity with the hazards.

No. 32. Oct. 3, 1947. Canton, Ohio, Tank Truck: Truck delivering gasoline to underground service station tanks when flames were seen at the valve compartment. Driver operated emergency

Acme Photo

Failure to properly guard against static is presumed cause of this fire at loading dock in bulk plant at Kingston Mines, Ill., Dec. 4, 1951.

Wide World Photos

Spillage from an overloaded full trailer which was on a main street in Detroit on July 1, 1948, caused this $20,000 fire despite very efficient fire department extinguishment with foam.

valve to stop flow. Fuel spilled into street and burning gasoline entered sewer catch basin. Fuel leaks found in valves, but ignition source not determined.

No. 33. Nov. 26, 1948. Long Beach, Calif., Tank Full-Trailer: Tank truck in bulk plant pumping fuel into underground tanks. Fire occurred when vapors, escaping from hooded tank vents ignited at office heater. Trailer tank ruptured when vapor in trailer tank ignited explosively. Quick fire department control was secured with water fog and foam.

No. 34. Sept. 26, 1949. Flint, Mich., Tank Full-Trailer (Double): Fire and explosion just before the double bottom 10,000-gallon capacity tank truck completed unloading at bulk station. Origin of fire in pump section of truck with ignition of vapors presumed from exhaust. A 20,000-gallon above-ground tank at bulk plant also involved. Seven 2½-inch hose lines used to control spread of fire by cooling. Loss estimated at $20,850.

No. 35. Dec. 4, 1951. Kingston Mines, Ill., Tank Semi-Trailer: Fire occurred during loading at dock. Exact cause not known but believed to have been from failure to properly guard against static electricity. Tank truck destroyed and fire fed by gasoline bleeding from supply tank when shut-off valve did not work properly. Four fire departments responded but were handicapped by lack of water. A foam generator was used and firemen succeeded in preventing spread to several near-by 1,000,000-gallon tanks of gasoline. Loss is estimated at $100,000.

Overloading

Then there is the overloading hazard, overloading the tanks of the trucks. Good practices are well established for tank "outage" but this phase of safety seems to be overlooked for the dubious benefits of greater capacity in more cases than we would have imagined, based on this sample of fire record experience. The control of this hazard is strictly up to the petroleum hauler as there is no practical way for fire officials to supervise the loading of each vehicle.

No. 36. Nov. 19, 1946. Peabody, Mass., Tank Semi-Trailer: Trailer tank (3,500-gallon capacity) was overloaded at bulk station. Gasoline slopped into overflow trough on top of tank and spilled down to exhaust pipe of tractor as vehicle proceeded on public highway downgrade. A flash fire occurred at tank vent. Fire extinguished after 2 hours.

No. 37. July 17, 1947. Waukegan, Illinois, Tank Truck: Overflow of 4,000 gallons gasoline tank truck caused spill as truck was proceeding up a grade. Spilled fuel ignited, possibly from static charge, leaving trail of fire behind truck. Severe exposure hazard to hotel, warehouse and parked cars. Fire department used hose lines to cool burning truck and protect exposures.

No. 38. July 1, 1948. Detroit, Michigan, Tank Semi- and Full-Trailer: Fire noted first under portion of chassis of rear trailer while vehicle in motion. Fire department believes ignition of spillage from overload by spark from static drag chain. (Drag chains now not recommended for static protection.) Fire spread over both trailers, 4 wood dwellings and two parked cars. Fire involved about 2,500 gallons of the 10,000 gallons in the trailers.

No. 39. Sept. 28, 1948. Boston, Mass., Tank-Semi-Trailer: Tanker at fuel loading rack at airport. Tank (capacity 4,600 gallons) was overfilled and fuel overflowed, vaporized and ignited at open flame flare marking construction work in vicinity. Fire damaged two fuel trucks. Airport and city equipment extinguished fire with CO_2 and foam.

Tragic Finale

There is always a freak accident in every fire record and a tragic one is included here to serve as a warning of the type of unthinkable accident that sometimes does occur.

No. 40. Dec. 2, 1951. Middlesex, N. C., Tank Truck: A nearly empty tank truck was parked in the private yard of the operator. His children were playing on the truck and fired a cap pistol near one of vents causing an explosion which killed four children, three being the operator's sons.

British Fire Tests of Fibreboard

Following World War II, the British government Department of Scientific and Industrial Research and the Fire Offices' Committee, composed of the fire managers of British insurance companies, established a Joint Fire Research Organization. This organization took over the FOC testing station at Elstree in Hertfordshire and the government provided the technical staff. The organization is governed by a Fire Research Board of which the Rt. Hon. the Viscount Falmouth is chairman and which includes in its membership such persons as H. M. Smith, His Majesty's Chief Inspector of Fire Brigades, and W. H. Tuckey, Director of the Fire Offices' Committee Fire Protection Association. Samuel H. Clarke is Director of Fire Research and in charge of the permanent research staff.

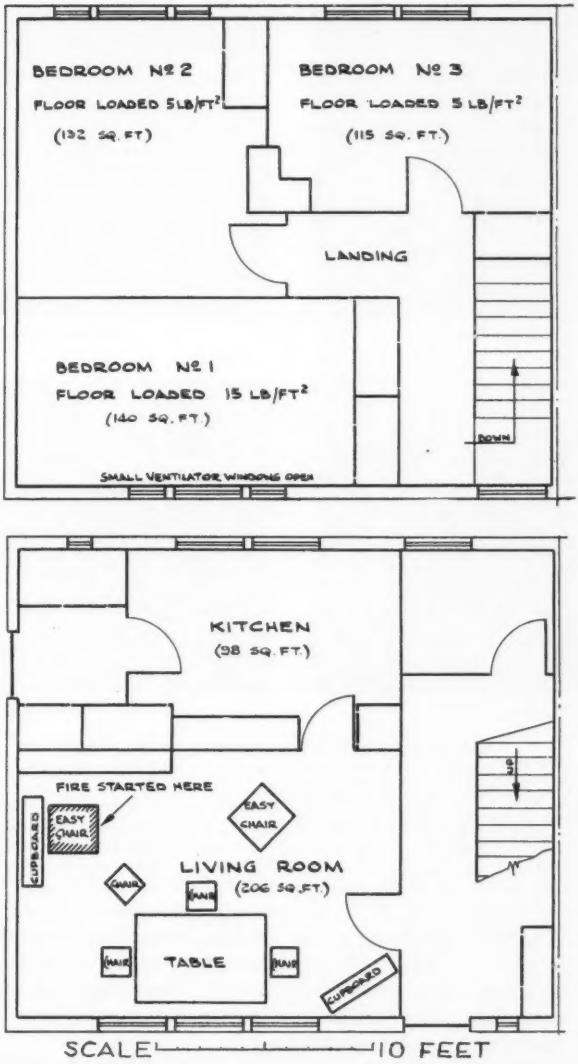
Most of the data here presented are from "Fire Research 1950," the annual report of the Fire Research Board. "Fire Research 1950" is a 64-page pamphlet published by H.M. Stationery Office (2 shillings, sixpence, available in the U. S. from British Information Services, 20 Rockefeller Plaza, New York 20, N. Y., 65¢).

The usual or "traditional" construction of English dwellings has been with solid brick outside walls, wood joist floors and roofs. Usually roofs have not been boarded, but slates or tiles were fastened to slats on the joists. The ceiling finish has been plaster on wood lath, while interior walls have usually been of brick or cinder concrete, finished with plaster. The use of wallboards instead of plaster finish has been considered a departure from tradition. The Fire Research Organization has fire service statistics to show that, while fire frequency is no greater, damage per fire is running higher in the post-war non-traditional dwellings, than in either pre-war or post-war dwellings of traditional construction. An opportunity developed late in 1949 to make a large scale fire test on two dwellings. The principal departure from traditional design was in the wall and ceiling finish. (Roofs were slate on wood slats on steel frames in the test houses.) The following summary of the test results is as published in "Fire Research 1950," and with illustrations from the report. Director Clarke kindly furnished the floor plans of the test dwellings and considerable additional data. Captions and page references to diagrams are not verbatim, but otherwise the language of the published report is used.

Details of Fire Tests

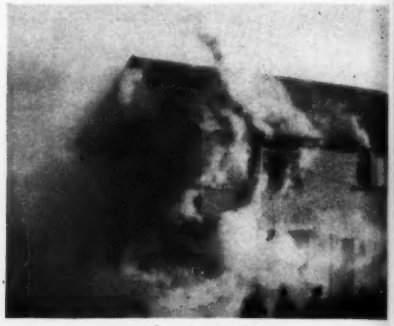
The walls and ceilings of two houses were lined throughout with fibre insulating board, and the partitions were also constructed of this material mounted on wooden studding. The second house differed from the first in that an additional lining of 3/8 inch plasterboard covered the whole of the insulating board of the walls and ceilings. The living rooms and bedrooms of both houses were fitted with "mock-up" furniture, and the combustible content due to carpets and drapings was suitably represented.

In the house lined with fibre insulating board, the fire, which was ignited in the living room, spread very rapidly. The whole room was involved within five minutes, and the fire would have rendered escape from the first floor hazardous if not impossible within seven minutes. The first



The layout of the houses is shown: two floors with open stairway and bedrooms on upper floor. Mock-up furniture is used in living room and combustibles are placed in bedrooms to give a loading of combustible material roughly proportional to loadings observed in lived-in dwellings. Time factors in fires could be varied by fire loading and ventilation. In U. S. and Canadian houses earlier ignition and faster flame spread on combustible surfaces could be expected where winter heating results in moisture content of furniture and wood of 5 or 6 percent and relative humidities 10 to 15 percent. Moisture content for furniture and wood in these tests was 11 percent, inside temperature 65 degrees Fahrenheit and relative humidity 40 percent.

Before fire.



After 6 minutes.

After 12 minutes.

After 19 minutes.

GROWTH OF FIRE — UNCOVERED FIBREBOARD

Progress of the fire in 1949 British full scale fire test of dwelling where interior wall, partition and ceiling surfaces were of fibre insulating board meeting British Standard No. 1142. The material had a density of 0.25 to 0.3 grams per cubic centimeter in sheets ½ inch thick and 3½ by 8½ feet. Boards available for the test were some of wood fibre, some of sugar cane fibre. Where in the two buildings each type was installed was not reported, the Research Station staff being satisfied that no differences between the specimens would be significant in relation to the conditions being studied. Sheets were nailed to wood studs and painted one coat of a sizing and two coats of an oil-bound water paint.

floor collapsed within fifteen minutes, and the roof within nineteen minutes. By comparison, the spread of fire in the plasterboard-lined house was much slower in its initial stages, some 23 minutes being taken by the fire to involve the whole of the downstairs room, escape being unlikely from the first floor room after 26½ minutes. Thereafter the progress of events was nearly as rapid as in the house lined with fibre insulating board. Thus the extra layer of plasterboard was extremely useful in retarding the spread of fire but did not increase substantially the fire resistance of the structure once the fire had become established. Photographs of corresponding stages of progress of the fires are shown.

Discussion of Test and Results

The experimental arrangements ensured that as far as possible the initial stages of the fires were identical and did not depend on the peculiarities of the structure of the building; in practice, the igniting source may be too small to start a continuing fire in a plasterboard-lined room, where it

Before fire.

After 24 minutes.

After 32 minutes.

After 40 minutes.

GROWTH OF FIRE — PLASTERBOARD COVER

Progress of the fire in 1949 British full scale fire test of dwelling where interior wall, partition and ceiling surfaces were a plasterboard over a fibre insulating board. The plasterboard was gypsum plaster between heavy paper facings conforming to British Standard No. 1230 with a total thickness of ⅜ inch. Wind velocity at time of these fires was about 5 miles per hour, outside temperature 40 degrees Fahrenheit and outside relative humidity 85 percent.

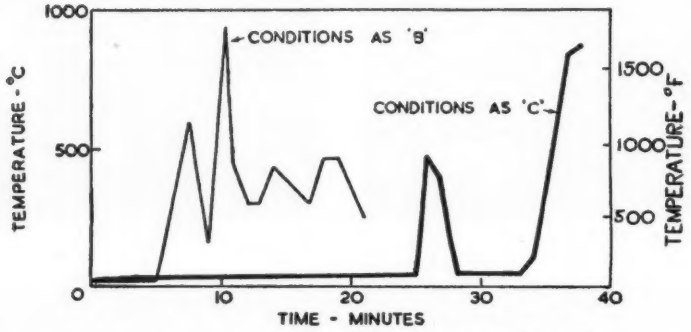
would do so with a fibre insulating board lining. The advantage would therefore be greater than indicated in these tests where it was arranged that a continuing fire would be started in each case.

During the tests complete records of the temperature were made in each of the rooms; curves comparing the growth of the fire in the living rooms (the rooms in which the fire originated) of both houses with the standard time-temperature curve are shown. Measurements of the radiation from the burning buildings were made throughout the tests.

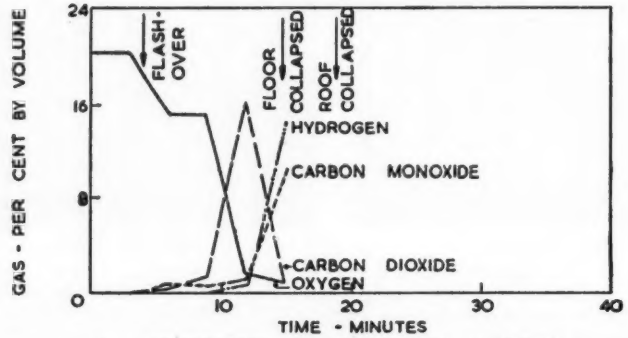
The opportunity was taken to observe the changes in the composition of the atmosphere in two bedrooms in each of the houses.

Analyses have been published of the atmospheres in enclosures in which a variety of combustibles have been burned under controlled conditions, but so far as is known there are no other records of full scale fires in which the variation of the composition of the atmosphere during the course of the fire has been observed continuously; great caution would therefore be necessary in attempting to apply earlier laboratory results to actual conditions.

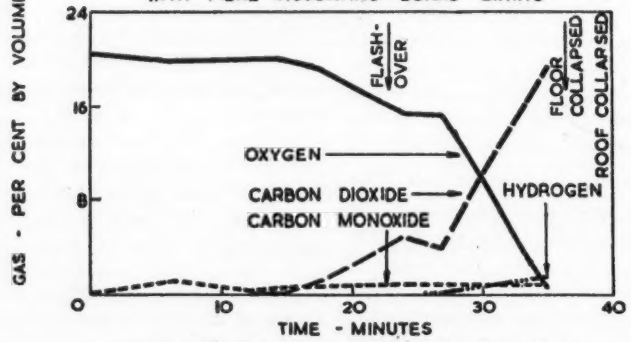
ATMOSPHERIC RECORDS IN BEDROOMS
CLOSED DOORS



A - AIR TEMPERATURE AT CEILING LEVEL

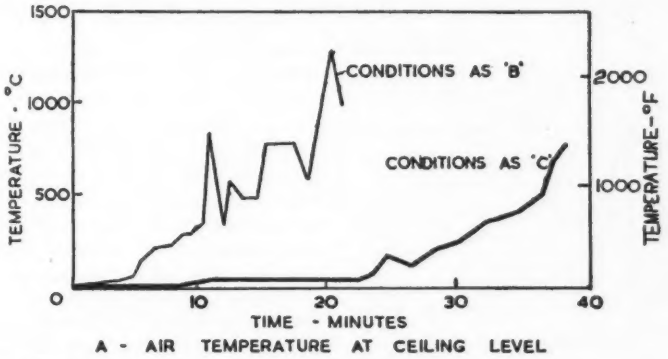


B - COMPOSITION OF ATMOSPHERE IN ROOM WITH FIBRE INSULATING BOARD LINING

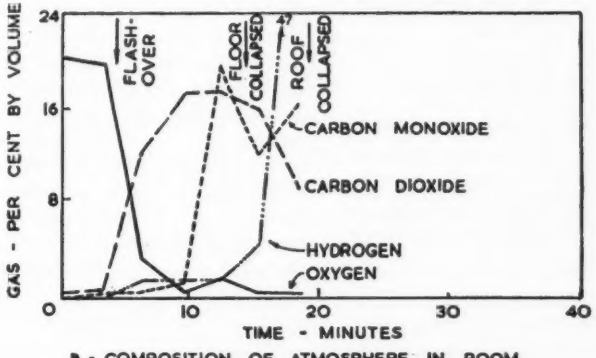


C - COMPOSITION OF ATMOSPHERE IN ROOM WITH FIBRE INSULATING BOARD LINING COVERED WITH PLASTERBOARD

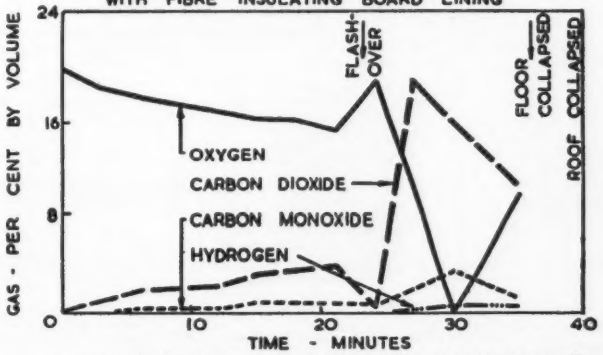
ATMOSPHERIC RECORDS IN BEDROOMS OPEN DOORS



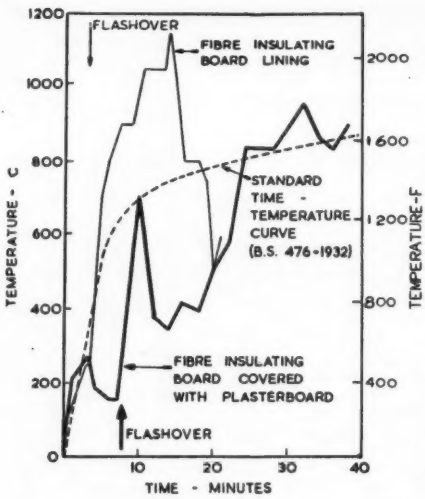
A - AIR TEMPERATURE AT CEILING LEVEL



B - COMPOSITION OF ATMOSPHERE IN ROOM WITH FIBRE INSULATING BOARD LINING



C - COMPOSITION OF ATMOSPHERE IN ROOM WITH FIBRE INSULATING BOARD LINING COVERED WITH PLASTERBOARD



LIVING ROOM FIRES
TIME-TEMPERATURE CURVES

The observed time-temperature relationships of the fires in the living rooms of the two dwellings tested compared to the British Standard Time-Temperature Curve used for reference in fire testing work. This curve is substantially the same as the curve sponsored jointly by the NFPA and testing agencies in the United States.

In the experiments, air was drawn continuously from the rooms and sampled every three minutes. Records were also made of the density of smoke in each of the rooms. In each house one bedroom had the door shut, while in the other room the door was left open. The results of the observations together with the temperature in the rooms are recorded graphically. The composition of the atmosphere changed continuously from that typical of products of combustion to those of destructive distillation as the fire developed. At first, the composition of the products approached that of a flue gas, being high in carbon dioxide and low in oxygen and combustible gases such as carbon monoxide and hydrogen. When the flashover stage was reached the composition changed rapidly, presumably because the oxygen supply could not keep pace with the supply of combustibles; the concentrations of carbon monoxide and other combustible gases increased, while those of carbon dioxide and oxygen decreased, and the rooms became smoke-logged. Times at which significant changes in smoke density and in the composition of the atmosphere occurred are summarized in the table below.

Conditions in Bedrooms in Burning Houses.

Wall lining	Bedroom door	Approximate times (minutes) at which rooms became uninhabitable on account of		
		hot gases	very dense smoke	toxic gases
Insulating board	Open	4½	5¼	3–6
	Closed	6	7¾	9–12
Insulating board covered with plasterboard	Open	24	9½	24–30
	Closed	25½	24½	27–35

Protecting Closed Vessels Against Explosions*

By E. W. Cousins and P. E. Cotton
Factory Mutual Engineering Division

If the maximum pressure is permitted to develop, it is not economical to build tanks or similar vessels to withstand without damage an internal explosion. The maximum pressure can be reduced by using rupture disks to relieve the explosion. Data supported by tests are presented to permit design of disks for various sizes and strengths of vessels for various gases and vapors.

* * * * *

Many pieces of industrial equipment—mixers, churns, reactors, autoclaves—may unavoidably contain mixtures of combustible gas or vapors. These gases may cause an internal explosion. To design a vessel thick enough to withstand such a blast is usually impractical (a tank normally operating at 25 psig would have to have its thickness increased by a factor of 5 to 10 to withstand the rapid stresses of an internal explosion).

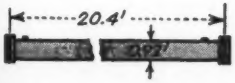
*Based on a talk presented by Mr. Cousins at the 55th Annual Meeting of the NFPA held in Detroit, Mich., May 7-11, 1951. (Program Item No. 58.)

The economical way to make these vessels safe is, of course, to reduce the pressure. In some cases, inert gas can be added to make the gas or vapor mixture nonflammable or to greatly reduce the flammability. The alternate method is through the use of bursting disks. The difficulty of this latter method is that very little data have been available with regard to the effect of disk strength and vent area on the maximum explosion pressure.

Except for some data on open vents for containers operating at atmospheric pressure, and a paper by Merl D. Creech entitled "Combustion Explosions in Pressure Vessels Protected With Rupture Disks" published in Vol. 63, No. 7 of the *ASME Transactions,* most of the data available are for closed vessels of 1 liter capacity.

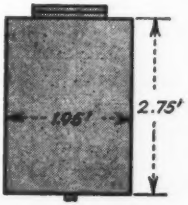
Recent Factory Mutual Tests

Tests were conducted by Factory Mutual Laboratories with mixtures (at maximum explosiveness) of hydrogen and air and of propane and air. Initial pressures were 0, 15, and 45 psig. Ratio of venting area to volume was made variable in vessels of



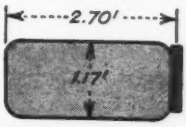
Volume—14.0 cu. ft.
L/D—22.1

Figure 1. Pipe.



Volume—7.6 cu.ft.
L/D—1.41

Figure 2. Drum.



Volume—3.0 cu. ft.
L/D—2.30

Figure 3. Tank.

Figures 1, 2 and 3. Dimension of explosion test vessels used in tests at O psig initial pressure.

1.1 to 20 cu. ft. capacity. Several strengths of disk were used.

The vessels used are shown in Figures 1-4. Test vessels 1, 2, 3 were used at 0 psig initial pressure. Vessel 4 was especially constructed to withstand the high explosion pressures developed in tests at higher initial pressures.

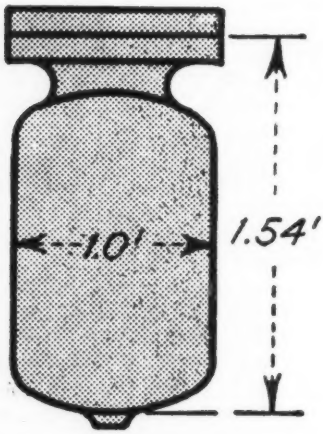


Figure 4. High pressure test vessel used to withstand higher initial test pressures. The volume is 1.13 cu. ft.; the L/D ratio: 1.54.

The hydrogen-air mixture was intended to represent a relatively rapid-rate burning material; the propane-air mixture a medium-rate burning material comparable to many solvent vapors. The particular concentration ratios of hydrogen to air (40%-60% respectively) and propane to air (5%-95% respectively) were chosen to give maximum pressure of explosion, maximum rate of burning and reliability of ignition. The gases were thoroughly mixed, lighted by an electric match.

Disks, used for tests at initial pressures above atmospheric were 2S-O aluminum of various thicknesses. Disks of hard Monel, spring-temper brass and soft copper were also used. All of the disk material (in the size and thickness to be used) was burst by subjecting each type (5 samples) to a slow increase of air or nitrogen pressure prior to each condition tested to establish the average strength of the material used.

Explosion pressures were measured with an electronic apparatus especially designed for the measurement and recording of explosion pressure. The pressure-sensitive element is a condenser, one side of which is a diaphragm exposed to the pressure to be measured. Increasing pressure decreases the spacing between the plates of the condenser thereby increasing the capacitance. The remainder of the apparatus is a bridge circuit for measuring the change in capacitance of the sensitive element.* The change is displayed on a cathode ray tube

*Detailed description of this apparatus published in the November 1947 issue of *Electronics* magazine (McGraw-Hill Publishing Co., 330 West 42nd St., New York, N. Y.).

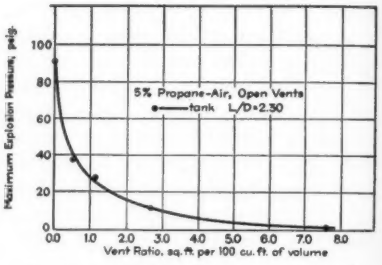


Figure 5. The effect of open vents on the maximum pressure developed by hydrogen-air mixtures when initiated at atmospheric pressure.

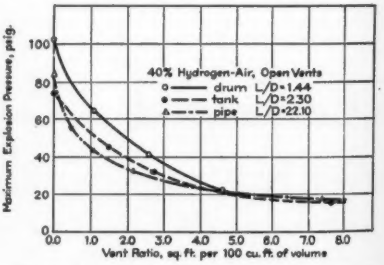


Figure 6. Propane-air mixture explosion pressures with open vents initiated at atmospheric pressure.

where it is recorded as a photograph of the pressure time diagram shown by an oscilloscope. Timing marks are made at intervals of 1/60th second.

Results of Tests at Atmospheric Pressure

Figures 5 and 6 show the effect of open vent areas on the maximum pressure developed by explosions initiated at atmospheric pressure with hydrogen-air and propane-air mixtures. (Each point the average of five tests.) The effect of L/D (ratio of length to diameter of the vessel) is illustrated in Figure 5. Because the container volumes did not vary in the same order as L/D, the effect of the volume of the vessel is slight. Because the explosion pressure in the tank differed from that in the drum by only 12 psig maximum in the range of vent ratios between 1.0 and 5.0 per 100 cu. ft., all later tests at 0 psig initial pressure were run with the tank. As expected, Figure 6 shows that the slower burning propane-air mixture is vented more easily than hydrogen-air.

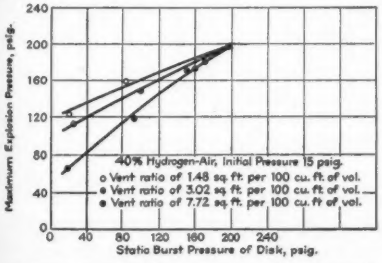

Maximum Explosion Pressure, psig.
240
200
160
120
80
40
0
0 40 80 120 160 200 240
Static Burst Pressure of Disk, psig.
40% Hydrogen-Air, Initial Pressure 15 psig.
o Vent ratio of 1.48 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 3.02 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 7.72 sq. ft. per 100 cu. ft. of vol.

Figure 7. The effect of rupture disk strength and vent ratio on maximum explosion pressure in a hydrogen-air mixture initiated at 15 psig.

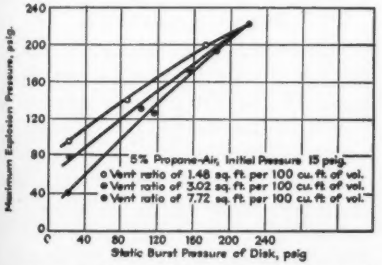

Maximum Explosion Pressure, psig.
240
200
160
120
80
40
0
0 40 80 120 160 200 240
Static Burst Pressure of Disk, psig
5% Propane-Air, Initial Pressure 15 psig.
o Vent ratio of 1.48 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 3.02 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 7.72 sq. ft. per 100 cu. ft. of vol.

Figure 8. The effect of rupture disk strength and vent ratio on maximum explosion pressure in a propane-air mixture initiated at 15 psig.

Effect of Disk Strength at Above-Atmospheric Pressures

The effect of rupture disk strength and vent ratio on maximum explosion pressure at initial pressure of 15 psig is illustrated in Figures 7 and 8. (Each point is the average of five tests.) For hydrogen-air and propane-air the closed vessel maximum explosion pressures are 198 psig and 220 psig respectively. These are maximum internal pressures to which a vessel of similar L/D ratio would be exposed by explosion of gases of similar burning rates and same initial conditions. The extent to which these pressures are reduced by venting is shown by the three curves.

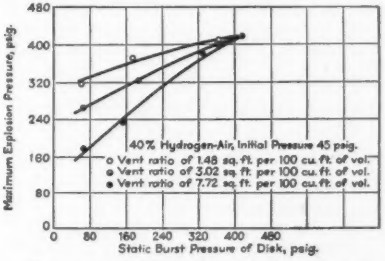

Maximum Explosion Pressure, psig.
480
400
320
240
160
80
0
0 80 160 240 320 400 480
Static Burst Pressure of Disk, psig.
40% Hydrogen-Air, Initial Pressure 45 psig.
o Vent ratio of 1.48 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 3.02 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 7.72 sq. ft. per 100 cu. ft. of vol.

Figure 9. At higher (45 psig.) initial pressures than in Figure 7, but with the same mixture and vent ratios, the maximum pressure increases from 198 to 417 psig. Explosion pressure increases as vent ratio decreases.

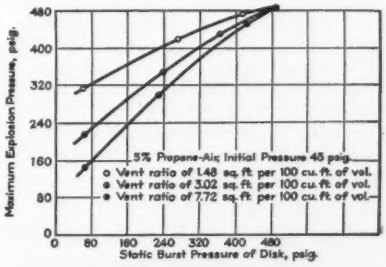

Maximum Explosion Pressure, psig.
480
400
320
240
160
80
0
0 80 160 240 320 400 480
Static Burst Pressure of Disk, psig.
5% Propane-Air, Initial Pressure 45 psig.
o Vent ratio of 1.48 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 3.02 sq. ft. per 100 cu. ft. of vol.
• Vent ratio of 7.72 sq. ft. per 100 cu. ft. of vol.

Figure 10. The propane-air mixture at an initial pressure of 45 psig produces a maximum pressure of 489 psig rather than 220 psig as shown in Figure 8 where the initial pressure was 15 psig. Explosion pressure increases as strength of disks increases.

Effect at 45 Pounds Initial Pressure

With the same conditions as illustrated in Figures 7 and 8 except that data in Figures 9 and 10 are for 45 psig initial pressure, the maximum internal pressures are 417 psig and 489 psig for hydrogen-air and propane-air respectively. As would be expected, the explosion pressure increases as disks of increasing strength are used. Explosion pressure also increases as the vent ratio is decreased.

The difference in burning rates on "ventability" is illustrated by comparing the graphs for hydrogen-air (Figures 5, 7 and 9) with those for propane-air (Figures 6, 8 and 10). Even though propane-air produces a greater *closed* vessel pressure than hydrogen-air, the *vented* hydrogen-air explosion pressures (Figure 5) exceed equally vented propane-air explosion pressures in most of the range of conditions tested. The faster burning rate of hydrogen permits higher pressures to develop in the time interval between the bursting of the disk and the instant the venting rate overtakes the rate of production of combustion products.

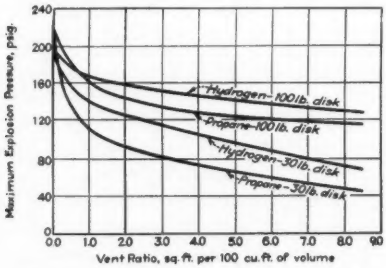


Figure 11. As vent ratio increases explosion pressures decrease. This graph shows data on 30 lb. and 100 lb. disks.

How Vent Ratio Reduces Explosion Pressures

The effect of vent ratio is illustrated by Figures 11 and 12 derived from the direct plot of the data by finding the explosion pressure at the tested vent ratios for arbitrarily selected disk strengths. Explosion pressure was then plotted against vent ratio for each selected disk strength to give an explosion pressure-vent ratio which is easier to apply to problems of existing equipment or new designs.

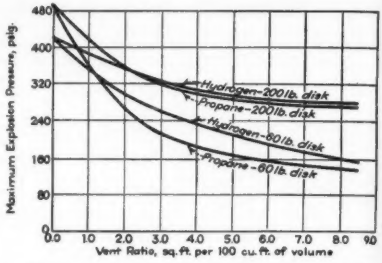


Figure 12. Disks of 60 lb. and 200 lb. strength were selected for this graph to show relationship of vent ratio to explosion pressures.

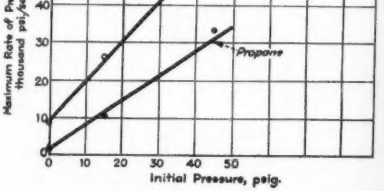


Figure 13. The maximum rate of pressure rise as related to initial pressure is illustrated. Note that the maximum for hydrogen air, for instance, is 26,000 psi per second when the initial pressure is 15 psig, 57,000 psi when 45 psig.

Rates of Pressure Rise

The relation of maximum rate-of-pressure rise to initial pressure is shown in Figure 13. Points for initial pressures of 15 and 45 psig are from this investigation and are averages of all values except those involving the largest vent. Points for 0 psig initial pressure were obtained from unpublished data from experiments by Eastman Kodak Co. and for propane at 0 psig are actually for acetone and toluene which have similar burning rates.

TABLE No. I

Bursting Disk Material	Vent Circle Diameter (Inches)	Disk Thickness, (Inches)	Static Burst Pressure, Psig.	Dynamic Burst Pressure, Psig.	Maximum Explosion Pressure, Psig.	Max. Explosion Press., AL Disk Same Strength, Psig.
Aluminum, 2S–O	4.00	0.0060	64.5	73	190	...
Aluminum, 2S–O	4.00	0.0170	153	169	223	...
Aluminum, 2S–O	4.00	0.0310	272	267	330	...
Brass, Spring temper	4.00	0.0080	183	187	258	267
Copper, electrolytic	2.50	0.0027	63.8	71	260	265
Monel, full hard	2.50	0.0020	84.6	84	251	274

Using Other Metals for Disks

Supplementary tests were made to determine if there would be any difference between the static and dynamic bursting pressures of disks made of metals other than aluminum. The additional metals used were spring-tempered brass, electrolytic sheet copper, and full-hard monel strip. It will be noted from Table I below that the difference in maximum explosion pressure between the three other metals and aluminum is, as would be expected, from their relative ductility. However, the differences are not statistically significant and are small enough to permit data derived with aluminum disks to be applied to other metals. The ratios of dynamic burst pressure to static burst pressure for the metals are also in logical order but the differences are again not statistically significant.

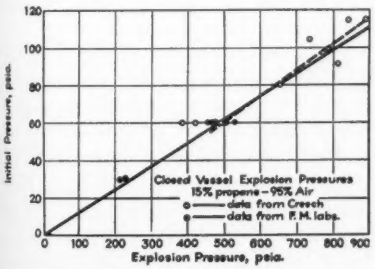


Figure 14. The Factory Mutual Laboratory test results are compared to data obtained from M. D. Creech's work (1941) on closed vessel explosion pressures.

Comparison of Present and Past Tests

The tests made by Creech,* reported in 1941, using propane-air mixtures, were conducted in a container 2 ft. in diameter and 10 ft. long. There were three spark plugs for simultaneous ignition at 3 points along the container so the L/D ratios would be about 1.7 if all were used or 5.0 if only the one near the end was used. Pressures were measured at three points along the container using engine indicators of the conventional type. Results of the closed vessel tests in comparison with those of the present investigation are shown in Figure 14. Note that the maximum explosion pressures are in reasonably close agreement but that the rate-of-pressure rise of the present investigation is very much greater. A small part of this difference is undoubtedly due to the greater L/D of Creech's container but the greater part is due to the difference in method of pressure measurement. The electronic gage has a natural frequency of many tens of thousands of cycles per second and, therefore, can follow the rapid pressure changes much more closely than the engine indicator which has a natural frequency in the hundreds of cycles per second.

Comparison of tests using bursting disks can be made only in a qualitative way. Most of the tests reported by Creech were

*See page 225 for reference to the work by M. D. Creech.

made at initial pressures higher than those of the present investigation and not enough tests were made to show the difference in effect of disks of different strengths. However, comparisons of ratios of initial and explosion pressures show a much greater effectiveness for a given vent ratio for Creech's data than indicated by our data. Again, this is due to the method of pressure measurement since the speed of response of the engine indicator is too slow to accurately follow the rapid pressure change and record the true maximum pressure. Tables II and III give comparison data for closed and vented vessels.

TABLE II

Comparison of Data from Creech and F.M. Labs. for Closed Vessel Tests with 5% Propane — 95% Air at Initial Pressure of 45 psig.

Creech L/D=5.8		F.M. Labs. L/D=1.54	
Maximum Explosion Pressure—psig.	Maximum Rate of Press. Rise—psi/sec.	Maximum Explosion Pressure—psig.	Maximum Rate of Press. Rise—psi/sec.
495	1850	530	42,200
385	1830	505	34,900
425	1355	475	36,400
495	1860	470	23,000
495	1860	465	16,500
Av. 459	Av. 1750	Av. 489	Av. 30,600

TABLE III

Comparison of Data from Creech and F.M. Labs. for Vented Explosions with 5% Propane — 95% Air.

Vent Ratio—Sq. Ft. per 100 Cu. Ft Volume	Creech Static Burst Pressure—psia.	Creech Initial Pressure—psia.	Creech Ratio Expl. Press. to Initial Press.	F.M. Labs. Ratio* Expl. Press. to Initial Press.
	66	60	4.25	
	66	60	4.75	
0.28	66	60	4.25	7.6
	122	99	4.45	
	188	115	4.13	
	134	65	3.77	
	105	85	3.59	
1.1	75	65	3.31	5.8
	122	97	4.07	
	105	85	3.59	
	75	65	3.46	
	150	115	2.91	
2.5	105	85	2.53	3.9
	85	71	2.46	
	85	71	2.46	

*Note: Data are computed for vent ratios shown and for 65 psig disk strength and initial pressure of 60 psig.

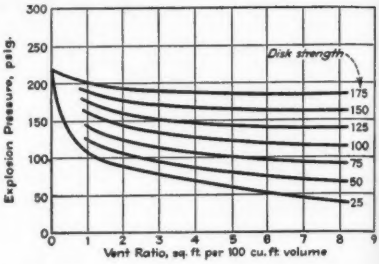


Figure 15. Explosion pressure — vent ratio relationship for bursting disks having static burst pressures (psig) as shown from design data for 40% hydrogen-air mixture with initial pressure at 15 psig.

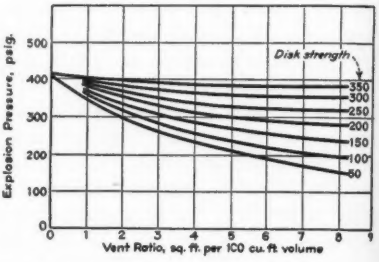


Figure 16. Explosion pressure — vent ratio relationship for bursting disks having static burst pressures (psig) as shown from design data for 40% hydrogen-air mixture with initial pressure at 45 psig.

Practical Application of Test Results

For practical use in design, results of the explosion research are presented in Figures 15, 16, 17 and 18. Each graph covers all data for one gas and one initial pressure and consists of curves showing the relationship between explosion and vent ratio for various disk strengths. For example, Figure 15 for hydrogen-air mixture at an initial pressure of 15 psig shows that the maximum explosion pressure that will occur in a vessel with no vent ratio (0.0) is 198 psig. If a vent ratio of 5 sq. ft. for each 100 cu. ft. of vessel volume is provided and equipped with a disk having a static burst strength of 25 psig, the explosion pressure will be limited to 90 psig. If the same area has a disk whose strength is

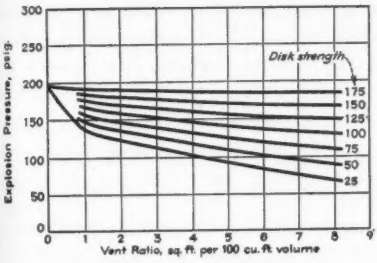


Figure 17. Explosion pressure — vent ratio relationship for bursting disks having static burst pressures (psig) as shown from design data for 5% propane-air mixture with initial pressure at 15 psig.

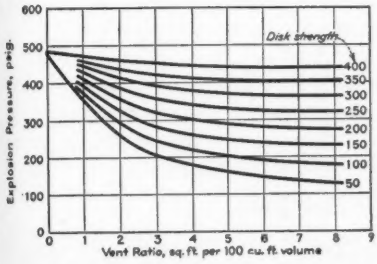


Figure 18. Explosion pressure-vent ratio relationship for bursting disks having static burst pressures (psig) as shown from design data for 5% propane-air mixture with initial pressure at 45 psig.

75 psig, the explosion pressure will be limited to 125 psig.

When it is not practical to use a single large disk because of space limitations or the impracticability of obtaining the required strength in a large diameter disk, a number of smaller disks of the required strength totaling the required area can be used. This is because, while for any given volume and disk strength the explosion pressure varies with the disk area, tests with varying volumes show that in general it is not the area alone that determines the explosion pressure but the ratio of vent area to volume.

Since the graphs were derived from tests of two gases at two initial pressures, good judgment will be required in their application to protection problems. Naturally, very few such problems will involve materials or conditions exactly equivalent to the test conditions. However, it is possible, by proper selection of one graph or a combination of two graphs, to apply the derived data to most protection problems that may be presented. One general rule should be noted in determining whether to apply the data for hydrogen or propane to the problem at hand. Since hydrogen's rapid burning rate is not widely met in other gases, the hydrogen data should be used for problems involving hydrogen or any mixture of combustible gases containing more than 20 percent hydrogen. The data for propane should be applied to all materials having moderate or slower burning rates such as organic solvent vapors. If there is doubt of the characteristics of the material involved and no data are available to indicate the proper selection, the safest course is to apply the data for hydrogen.

The application of the explosion pressure-vent ratio relationship has certain limitations determined by the scope of the investigation from which it was derived and the following specific instances are given to govern the use of the data developed.

1. These design graphs are not applicable to pipelines or long tanks. In such containers a "detonation" can occur for which the maximum pressures are in the thousands of pounds per square inch and venting is totally ineffective. At atmospheric initial pressure the critical L/D ratio is about 60 which reduces to 30 at an initial pressure of 15 psig. Critical lengths for higher initial pressures have not been established. Within this limitation the explosion pressure decreases with increasing L/D ratio so the graphs may be safely used for containers of L/D ratio greater than that of the test container (1.54). For L/D ratios between 1.54 and 1.0 an added safety factor should be considered.

2. Initial operating pressures above the scope of the investigation are not covered by it, although straight line extrapolation of the data up to 60 psig is probably safe. For initial pressures below 15 psig straight line extrapolation to 0 psig can be made with safety.

3. For temperatures much higher than the range of the investigation (50 to 90 deg. F.) the data should be applied with caution. As the temperature increases, the quantities, by weight, of combustibles decrease, other things being equal. At the same time, the initial energy level increases with the result that it is not known specifically how extreme temperatures affect explosion pressure or ventability.

4. The data apply to vents having an unobstructed discharge to atmosphere (after the disk bursts). That is, they are not applicable to vents discharging into ducts or other confining spaces.

5. Since an explosion vent is a method of spreading out a quantity of energy which would be harmful if confined, caution should be employed in determining where that energy can be spent safely. The placement of vents should be such that their discharge would not be directed at flimsy construction such as thin partitions, glass windows, etc. Nor should they be directed in a manner such that personnel would normally be within the discharge path while the hazard exists.

"Emergency—Dr. Red"

St. Paul's Hospital Fire, Dallas

"Dr. Red" was fire.

The Emergency came at 12:25 A.M.

At 12:25, the Sister Superior was awakened by a strange noise.

The strange noise came from the attic over the Nuns' Dormitory on the fifth floor of St. Paul's Hospital in Dallas.

St. Paul's Hospital on the morning of October 25, 1951 housed 254 patients, of which 21 were new born babies.

In 12 to 15 minutes all were evacuated safely in a mass rescue operation set in motion by the code signal "Emergency—Dr. Red" over the inner-communication system.

Outstanding services rendered by the Dallas Fire and Police Departments plus the efficient cooperation of ambulance services, taxicab operators, transit companies and groups of spectators spelled safety for all occupants and extinguishment of a potentially serious fire within one hour and 28 minutes.

The secret of both the successful evacuation and the successful fire fighting was preplanning.

Lack of automatic protection, serious construction deficiencies and inadequate exit facilities made the evacuation and extinguishment truly remarkable.

The Building

St. Paul's is a large hospital.

The "Main Building" was built in 1896-98 in the form of a "U" having a grade floor area of approximately 14,000 sq. ft. It was a typical brick, wood joist structure with a peak, slate covered roof on wood decking, on wood joists on wood beams, on wood posts. The ceiling on the top floor below the attic was metal lath and plaster. A treated wood pulp insulation (that would not support combustion) was

used to insulate the enclosed space between the wall studding and in the joist channels. The attic space was used for storage purposes and contained steam pipes, water lines and electrical wiring in conduit.

Neither the "Main Building" nor a large fire-resistive annex had automatic sprinkler or detection equipment.

Evacuation Facilities

The stair and elevator shafts in the "Main Building" were in process of being enclosed by noncombustible type partitions and during this work openings to the shafts on the first four floors had been temporarily sealed with plywood.

Steel (down to the second floor, wood below) exterior fire escapes were available on two sides of one wing of the "U". One other exterior steel escape was located on the interior court formed by the "U". An interior enclosed stairway and two enclosed elevators in the fire-resistive annex were accessible through connecting corridors on each floor from the Main Building. The evacuation plan called for the use of these enclosed annex stairs and in the emergency this plan was followed. No one needed to use the exterior escapes.

A stairway to the main entrance of the Main Building extended from grade to the second floor only.

Preplanning

In September 1951, St. Paul's adopted an evacuation plan. No drill had been held when this emergency occurred on October 25 although such a drill had been contemplated. The private fire brigade had not been fully organized. Despite these limitations, when the code signal "Emergency—Dr. Red" was sounded, the hospital staff

Acme Photo

Air view of St. Paul's showing destruction of attic area in one wing of the "U"-shaped building. Sprinkler protection was not afforded the wood joisted attic or the balance of the building and when fire was detected sparks were emitting from a crack in a metal lath and plaster ceiling on the fifth floor.

functioned with such efficiency it was evident that the evacuation program had been taken seriously. Because the staff functioned coolly in the emergency, there was no panic.

If the hospital's preplanning was of recent vintage, the Dallas Fire Department had, for many years, preplanned its operation for just such an emergency in St. Paul's. The first alarm at 12:25 was followed by a second and third at 12:33, when the Battalion Chief in charge of the first equipment found the attic full of smoke. At the same time he ordered a full evacuation of the hospital. When fire broke through the roof at 12:37, a fourth and fifth alarm was given by radio, and other apparatus, including all available ambulances, were called. The Fire Department massed fifteen engine companies, five aerial truck companies, 106 on-duty and 212 off-duty men.

Fire and Police Cooperation

The fire was fought and confined in the fifth floor and attic in one wing of the Main Building. Operating at night, with considerable smoke and heat in the attic obstructed by supporting wood braces, the fire department did a remarkable job. Aerial ladders were used extensively despite impediments of an iron fence, narrow driveways and numerous trees on the property. The only usable inside stairway (in the Annex) was "busy," being used for evacuation.

The Dallas Police Department assembled and convoyed ambulances, taxicabs, buses and private cars to transport patients to safety. They set up traffic blocks to handle spectators. They aided in the manual evacuation work. Police radio brought in ambulances from outlying towns. The fire was tapped out at 1:53 A.M. By 9:00 P.M. the same day, all available space in St. Paul's was again in use although the bedrooms and wards in the Main Building were left vacant because of the hazard of loose plaster on ceilings. Fire damage was confined to the attic over one wing and adjoining roof. Plastered interior walls and ceilings suffered considerable water damage. Early estimates place the loss at $125,000.

But How Much Better

But, how much better it might have been!

Instead of a forced evacuation of the ill and the invalid,

Instead of an army of fire fighters, police and volunteers risking death in a hazardous night battle against an uncontrolled fire in an unsafe structure,

Instead of these, if "Mr. Automatic Sprinkler" had been on hand to answer the "Emergency—Dr. Red" the patients would not have been disturbed, the building secured, the risks avoided. With all due credit to the Dallas Fire and Police Departments, to the Hospital Staff, to their insurance advisors and others concerned, it does not seem too much to expect that automatic sprinkler protection could have been provided some time during the 50 years the building has been housing the helpless and the newborn.

Kodak Park Paper Storage Fire

Fire in a paper storage area on the top floor of a five-story fire-resistive building in the Kodak Park Works of the Eastman Kodak Co. starting on Nov. 10, 1951, caused damage estimated at some two million dollars, and is of unusual interest not only because of the technical features involved but as an illustration of the possibility of severe fire loss even in a large industrial property with a reputation for an outstanding fire safety program.

The Building

Building No. 57 is a five-story reinforced concrete building approximately 122 by 545 ft. erected during 1936-37. The building is of flat slab, mushroom column construction, designed for a floor load of 250 lbs. per square foot except the roof which is designed as a floor with a load of 150 lbs. per square foot. The walls are non-bearing curtain walls made of two thicknesses of hollow tile. The outside is typical red hollow building tile and all inside tile is a high density hard burned tile known as "gray manganese tile" especially selected because of its resistance to acids.

The majority of the building is occupied by operations concerned with the manufacture of sensitive emulsions for photographic papers and the coating of these emulsions on the paper base.

Most of the 5th floor is used for storing baryta-coated photographic paper. This is essentially a high quality paper base with a coating of baryta (barium sulfite) applied to form the familiar smooth photographic paper surface. This is an intermediate operation between the making of the paper base itself and a subsequent coating with sensitive emulsion.

In addition to this large storage area, there is a small area at the north end of the building, cut off by a 6-in. gray manganese tile partition, used for the storage and preliminary mixing of chemicals in connection with emulsion manufacture. There are also two rooms along the east wall, one used for printing identifying material on the back of certain grades of paper, and the other used for paper inspection.

The Paper Storage

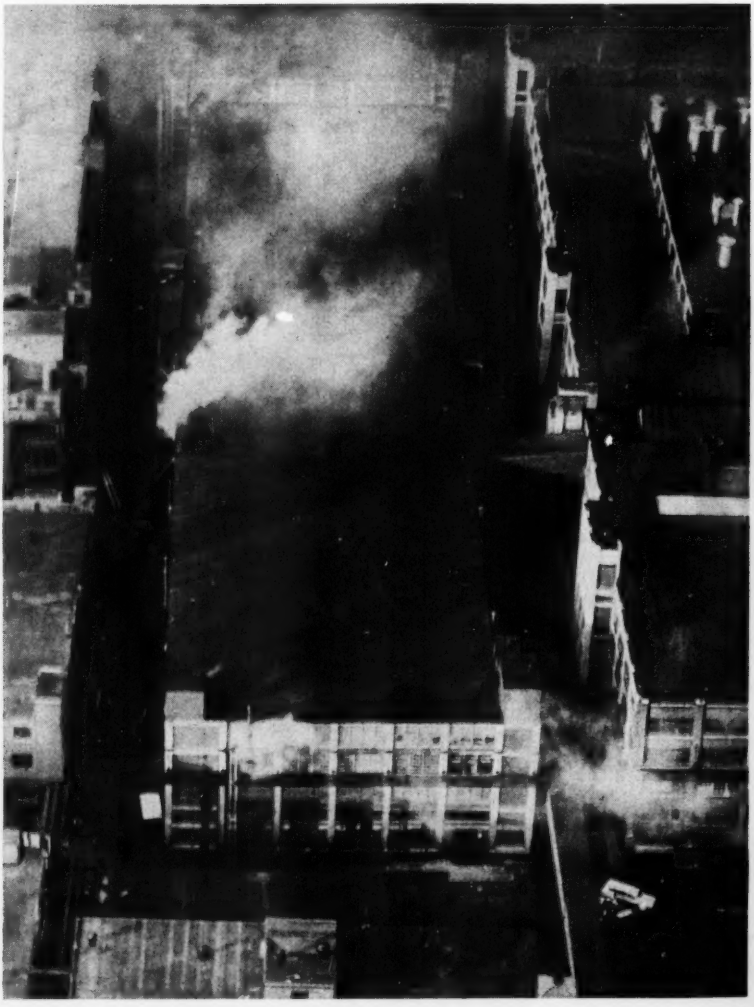
Rolls of baryta-coated paper were brought over the bridge from an adjoining building by specially designed electrically-powered roll trucks equipped with arms to lift and place the rolls in racks located in the storage area. Rolls are tightly wound and the end of the paper secured with adhesive paper tape. An exception is a small percentage of rolls intended for shipment to other plants. These are wrapped in kraft paper, including the ends.

The paper varies in thickness, both a single and double weight paper being made. A small percentage of the paper used for direct positive work is waterproofed by cellulose acetate coating on both sides. There is also a small amount of material known as stripping film base. It is covered with an extremely thin layer of nitrate material which in later processes may be stripped from its paper support. Fire tests do not indicate that these materials have appreciably greater fire hazard than the baryta-coated base itself.

At the time the building was erected, tests were made in regard to the need of

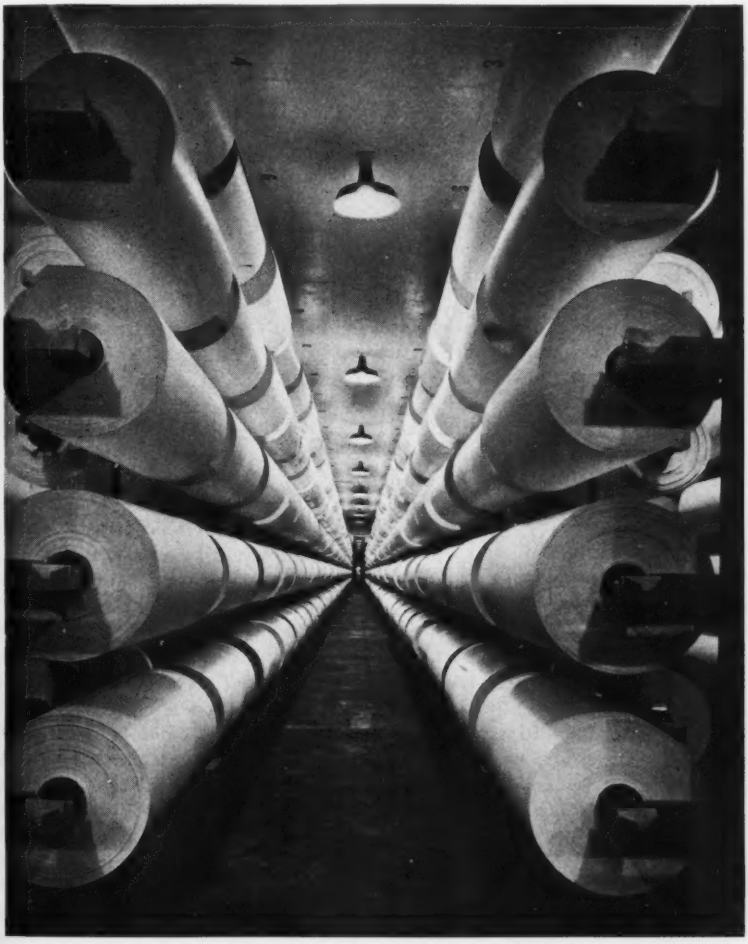
---

This report has been prepared by the Editor from data furnished by several NFPA members. Particular acknowledgment is made of the cooperation of the Eastman Kodak Co., which supplied complete data through Allen L. Cobb, Safety Director of the Kodak Park Works.



Looking south over Building 57 during the fire. Air supply to fire was restricted by solid walls without windows or access panels and by the solid reinforced concrete roof. By using a crane boom the walls were eventually breached to provide ventilation and permit entry for fire fighting, but with a free air supply the fire increased in intensity. According to one theory a fire such as this might well be handled by letting the fire starve itself through lack of oxygen, at the same time removing combustible materials by men wearing self-contained breathing apparatus.

providing sprinkler protection. It was found that the rolled paper ignited with difficulty, if at all, when subjected to the flame of a gasoline blow torch. The turned up edges of paper were very easily extinguished and, in fact, such fires went out of their own accord. A number of such tests were run and were witnessed by representatives of insurance organizations as well as Kodak Park engineers. In view of the possibility of water damage from the accidental breaking of sprinkler piping



Paper roll storage before the fire, aisle about 500 ft. long without any fire stop. A blow torch test had indicated that this paper would not ignite, and the possibility of water damage from sprinklers damaged by lift trucks had loomed larger than the danger of fire; hence no sprinklers in this area, though adjoining manufactuing areas were sprinklered. Some rolls were wrapped in Manila paper, more readily ignited than the photographic paper.

by the automatic roll trucks, it was concluded that the probability of ignition was remote and that if any ignition did occur such a fire could be very easily handled by first aid equipment. As a result sprinklers were not installed over the storage area.

Ventilation Equipment

The storage area of the 5th floor was heated and ventilated by a warm air system taking suction from an air shaft which received fresh air from outdoors or recirculated air. This air passed through a fan room containing a 50,000 cfm fan, then through fin coil heaters into a bag filter room, where it passed through canton flannel bags. There were 68 of these bags connected to a header plate, each bag being approximately 17 in. in diameter and 17 ft. long. This ventilating equipment was all located in the 4th floor of the building and supplies heated and filtered air to a duct, 4 x 8 ft., rising vertically from the filter room to the underside of the ceiling of the 5th floor. The fan and filter rooms were of gray manganese tile construction and the filter room was lined with canvas held in place with Ulmer cement and painted with Dulux enamel.

Fire Protection

Except for the roll area itself, the building was fully protected by automatic sprinklers supplied from the Kodak Park fire mains. Hose risers in each of the stair-towers were equipped with 2½-in. hose valves but no hose. First aid extinguishing appliances in the area were 2½-gallon water pump tanks.

Kodak Park Fire Department

The Kodak Park Fire Department is intended to render that service generally performed by a single city fire company. It consists of a Chief, 2 deputies, 4 captains, and 20 firemen operating on a four-shift basis to provide one company of five men and a captain on each operating shift. Equipment consists of a 750-gpm pumper, an older motor-driven hose truck, and the chief's car. This equipment is supplied with both 2½- and 1½-in. fire hose and the usual complement of combination nozzles and special devices. The apparatus is also equipped with McCaa oxygen breathing apparatus of the one-hour type approved by the U. S. Bureau of Mines for mine rescue work. The Fire Department personnel is trained in wearing this apparatus under the direction of a trainer qualified by the Bureau of Mines. There is also additional oxygen breathing equipment in various departments which is available in an emergency. Absorption gas masks of the all service type are also carried. Kodak Park has its own fire alarm system connected to the Kodak Park Fire Department headquarters. Kodak Park apparatus is equipped with two-way radio communication with the Kodak Park station which controls movement of trucks and railroad locomotives. Three fire alarm boxes located within Kodak Park connect to the Rochester City Fire Alarm Headquarters.

Start of the Fire

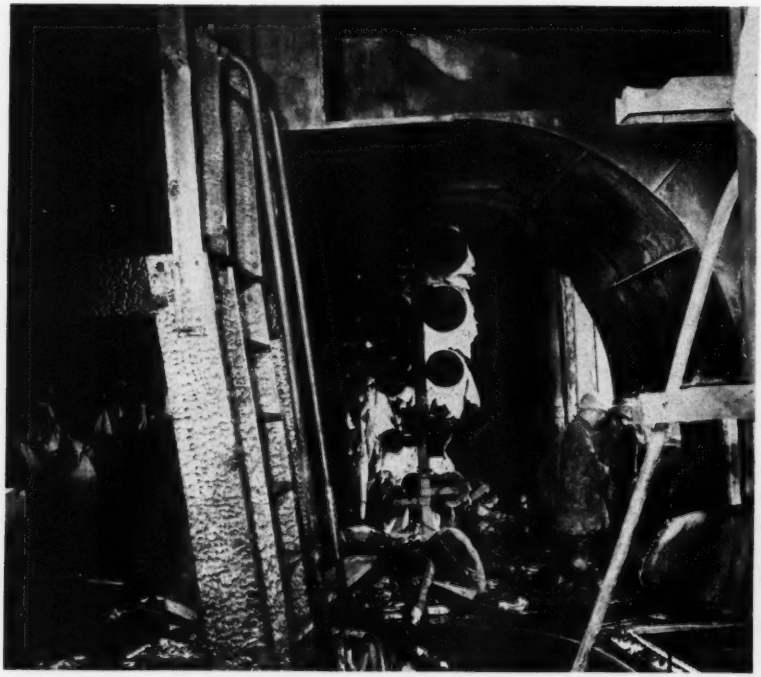
On the morning of Saturday, November 10th, employees were engaged in making alterations to the racks along the east wall of the building near the south end. The area was separated from the rest of the floor by a temporary partition of masonite on wood studs. There was arc welding work in connection with this operation. A permit for this work was secured in accordance with Kodak Park procedure. It was authorized by the Field Department supervisor, a representative of the Baryta Coating Department — which has jurisdiction over this area — and was checked by telephone with the Safety Department. This work had been checked at the beginning of the job, and because of the low ignition hazard, renewals were granted by telephone without going to the scene, but no permit had been issued for work inside any duct.

Near the center of the fire area. Paper largely consumed, steel supports wrecked.

A large opening was cut in the side of the horizontal duct at the point where it turns to drop into the fan room. This opening was first made with a hammer and cold chisel followed by cutting out the opening to proper dimensions with an electric rotary shear. It was found that there were two 1½-in. pipes installed crosswise of the duct as safety guards to prevent anyone, cleaning the duct from the inside, falling into the vertical section and it was necessary to remove these, which was done by oxy-acetylene cutting at the end nearest the new opening. Later the opposite end of the pipe inside the duct was burned off using an electric carbon arc. No checking was done within the bag room. The men working on the duct left for lunch about noon and no smoke was evident at that time.

It is believed that drops of molten metal, either from the oxy-acetylene operation or the later carbon arc burning, dropped through the vertical duct, bounced about 10 ft. horizontally from a small roofed-over area within the fan room to the bags. The fans had been shut down before the work was started.

The exact story of what happened in the bag room is not known, but it is believed that the sparks burned into several of the bags, starting smoldering fires in the dust and lint within perhaps four or five of these bags. This slow smoldering combustion with little air and under the elevated temperature of the fan room (steam coils were still turned on) resulted in the formation of considerable carbon monoxide but relatively little smoke, some of which was filtered out by the bags themselves. When actual flame did finally appear, the bags were already heated nearly to their



Air duct where sparks from cutting operations (oxyacetylene and electric arc) started fire. Work was done in opening of duct at right. Sparks fell to filter room below.

ignition temperatures and there was probably a considerable amount of carbon monoxide present in the room, resulting in a flash fire or mild explosion developing appreciable pressure.

At about 12:20 a watchman went through the fifth floor and noticed no smoke or unusual conditions. At approximately 12:30 a millwright assigned to checking the storage battery charging operation, returned and noticed some smoke. He climbed a platform ladder at the duct opening and noticed considerable smoke within the duct. He returned to the floor and started to turn in an alarm when a burst of flame erupted from the opening, extending about 20 ft. horizontally and apparently carrying with it a considerable amount of burning material. It is assumed that burning cloth from the bags themselves was discharged in this blast of flame and settled upon rolls over a large area of the floor.

Fire Fighting Operations

The four men in the area turned in the alarm and started to attack the numerous small fires with 2½-gallon pump tank extinguishers. One man removed the oxyacetylene cutting equipment. They were successful in extinguishing a number of the fires, but the two extinguishers became empty before they completed their work and while trying to refill them, the fires gained in intensity and the smoke increased, making it difficult to remain in the area.

The Kodak Park Fire Department on

Air filter room after the fire. Cloth dust bags, 17 in. in diameter by 17 ft. long, were ignited by sparks from cutting operation above. In the absence of sprinklers or other automatic protection in the room, or of automatic fire dampers, fire spread through the duct openings to ignite the paper stored on the floor above.

arrival entered at the southeast stairtower. Following normal Kodak Park practice, first entry was made with the all service type of mask due to the time required to put on and properly check the McCaa oxygen apparatus. A line of 1½-in. hose was stretched into the area and fire fighting operations begun. One man put on the McCaa apparatus but, because of haste in putting it on, may possibly have inhaled some room air and discharged it into the breathing bag of the apparatus, which has the effect of increasing the nitrogen content within the equipment. All of the men climbed five flights of stairs and were actively working to control the fire. Because of the exertion, coupled with the probably increased nitrogen content in his apparatus, the man wearing the McCaa apparatus collapsed and when his rescue was attempted by other men wearing absorption equipment, they found they were barely able to get out of the room themselves, due probably to the decreasing oxygen content in the area, there being no outside ventilation whatever.

Chief Van Lare of the Kodak Fire Department, on reaching the door, made a check of his men and on finding one missing, went in without replacing his gas mask, succeeded in locating the overcome fireman and dragged him to the door, after which Chief Van Lare himself was so seriously affected that he was not able to continue fire-fighting operations. The City Fire Department was then called, the first time in 25 years that they had been called to a fire in Kodak Park. At the time it was about 40 minutes after the start of the fire.

Mr. Cobb's Story

From this point on the progress of the fire is covered by the following personal account by Allen L. Cobb:

I came into the plant and on arrival found one fireman receiving artificial respiration and an inhalator in use under direction of a nurse from the Kodak Park Medical Department who had arrived with our ambulance. Another fireman was unconscious but breathing and awaiting the second trip of the ambulance. Chief Van Lare was very weak from smoke effects but told me the city had been called.

I then put on the McCaa apparatus. This equipment is provided with mouthpiece breathing connection and with so-called "nod and shake goggles" which are substantially gas tight but which cannot be worn over ordinary glasses. As I am quite nearsighted, I found it impractical to enter the area with this equipment, although breathing was satisfactory.

Arriving at the foot of the stairtower, I met the captain of the arriving company, who asked me regarding location of the risers and the extent of the fire. I informed him of the smoke conditions and the probable need for Chemox apparatus with which the City of Rochester is equipped. I then took Chief Van Lare to the Medical Department in my own car and stopped at the Safety Department, called two safety men—the Assistant Director, Mr. T. F. Wright, and Mr. R. J. Gabel—and picked up two sets of demand type of oxygen breathing equipment.

Returning to the scene, I found a number of ambulances had arrived and were carrying firemen from the first city company to the Medical Department, some 19 or 20 being quickly overcome by smoke as they attempted to enter the area without oxygen breathing equipment. As I went up the stairtower, Chief Slattery of the Rochester Department was being carried down.

I entered the area wearing the oxygen equipment and found that while the smoke was dense there was no heat or visible fire. About 4:00 P.M. on entering the east stairtower with another man, we were able to walk up along the east wall of the building and found a considerable number of rolls which had been on fire but which were not burning and were cold to the touch. I believe that active flaming in the area at this time had ceased, due to lack of oxygen and only glowing fire remained in a few areas. Smoke density, limiting visibility to about one foot, made fire fighting operations difficult and the Rochester Fire Department was not operating within the area at this time.

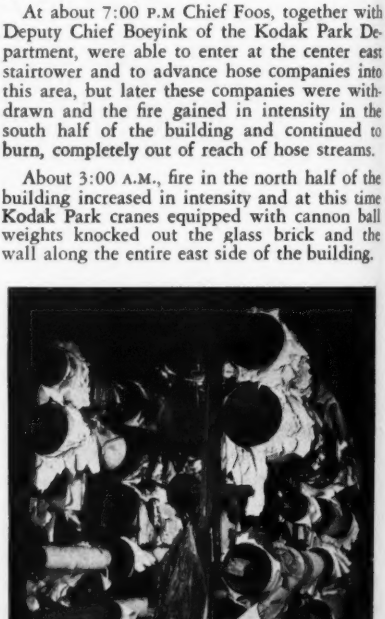
Meanwhile, part of the glass block wall at the south end of the building had been breached by the boom of a Kodak Park crane and a hose was operating through the broken glass.

At this point it appeared that the fire was under control. Additional cranes were obtained and additional glass block panels broken out in an attempt to clear the area of the smoke, but this also admitted fresh air, probably resulting in reignition of partially burned rolls. Shortly after this, it was noticed that water discharging from the four sprinklers at the foot of this ramp was very hot, indicating a general increased temperature in the area.

Additional fire companies were called in until there were six aerial ladders in operation with 11 city pumpers and a number of those from volunteer companies in the Monroe County Mutual Aid set-up. Special calls were made to the county organization for oxygen breathing apparatus and flood lighting equipment. Water supplies were adequate, the pressure at the Kodak Park Fire Department gauge showing a drop from 95 to 91 lbs. and the lowest pressure drop noticed in any stairtower was from 95 to 85 lbs. It is estimated that water used was about 4,000 gallons per minute.

At about 7:00 P.M Chief Foos, together with Deputy Chief Boeyink of the Kodak Park Department, were able to enter at the center east stairtower and to advance hose companies into this area, but later these companies were withdrawn and the fire gained in intensity in the south half of the building and continued to burn, completely out of reach of hose streams.

About 3:00 A.M., fire in the north half of the building increased in intensity and at this time Kodak Park cranes equipped with cannon ball weights knocked out the glass brick and the wall along the entire east side of the building.



These rolls at the south end of the building were within reach of hose streams.

During Sunday morning, I entered the center east stairtower with a captain and two firemen of the Kodak Park Fire Department with oxygen apparatus and a 2½-in. hose line. It was not possible to work much beyond the stairtower as the temperatures were quite high. Water striking the ceiling boiled off immediately.

On Sunday afternoon, the Rochester city firemen succeeded in entering parts of the area with hand lines. The fire was under control by 8:00 A.M. Monday.

Structural Damage

None of the roof slabs was broken through, but deflections were noted up to a maximum of 1¾ in. Core tests of the concrete made immediately showed varying strengths from 1750 lbs. to 3000 lbs., the Kodak acceptable minimum being 3000 lbs. Some spalling was noted around the corners of drop panels and some on column capitals, none on the slab itself. The gray manganese tile partitions stood up well and were not breached by fire in any area and showed only a small amount of spalling in one spot. A tin clad fire door showed severe damage, although it remained in position and prevented passage of fire into the sprinklered printing room.

An approximate idea of temperatures in this area is gained from the fusing of porcelain enamel on light fixtures, indicating temperatures in excess of 1600°F. It is believed that these temperatures continued for more than three hours.

While serious damage to the concrete roof slab was not immediately apparent, it was believed that much of this concrete would ultimately show a loss in strength and work was started immediately in removing the concrete roof slabs in the most seriously affected areas using air hammers.

Concrete which appeared in fair condition was very weak and separated readily under air hammers with loss of bond between the concrete and reinforcing steel and with separation of the aggregate from the matrix. It was necessary to replace almost 90% of the roof slab in the fire area and this was carried down the column capitals to the top of the cylindrical section of each column, thus fully exposing the supporting steel in this area and securing a good bond in the reconstruction.

Water Damage

The effectiveness of the waterproofing treatment of the floors was well demonstrated. Very little water came directly through the slab at any point, but there was leakage at expansion joints and around pipe sleeves, some of which dripped off pipes on the 4th floor on to material and equipment. For the most part, however, the only damage on the 4th floor was caused by about 3 inches of water accumulation on the floor slab itself. Lower floors also showed a little water damage.

Smoke

The burning of baryta-coated paper may have released some sulfur dioxide during the early part of the fire, although no irritating gases were noted. During later stages, hydrogen sulfide gas was noted, and it is known that barium sulfite may be reduced, releasing hydrogen sulfide at temperatures in excess of 600°F.

This fire door did its job for over three hours.

Large Loss Fires of 1951

An NFPA Staff Study

1951 was a disastrous year for large fire losses. During the year there were 302 fires in the United States and Canada with individual losses of $250,000 or more producing an aggregate loss of $213,310,000.

This shocking experience accounted for 24 percent of the total fire loss in these two countries.

The number of large loss fires in 1951 increased 24 percent over the previous year and caused about 40 percent more damage. The 268 large loss fires in 1948 were the largest number to occur in any year prior to last year.

Fatalities

There were 369 more fatalities in the 1951 large loss fires than in those of 1950. The six disasters involving largest loss of life were the West Frankfurt, Illinois mine explosion (119 killed), aircraft fires in flight over Elizabeth, New Jersey (56 killed), and enroute to Europe (53 killed), the aircraft crash fire near Decoto, California (50 killed), the tanker collision in the Gulf of Mexico (39 killed) and the Montreal Hospice fire (35 killed).

Sources of Information

These large loss fires, by virtue of their size and importance, have received in most instances careful scrutiny by investigating authorities and have thus been reported to the NFPA in sufficient detail and accuracy to permit analysis. The application of the lessons from these fires will accomplish a reduction in the number and serious effects of fires of all magnitudes.

It has been necessary to eliminate from this compilation a large number of fires (this year 196) originally reported as involving a loss of $250,000 or more, but which, by careful checking of actual property damages, were found to be of lesser magnitude.

Change in Method of Presentation

In the following analysis of the 1951 large loss fires an effort has been made to point out for the various occupancies involved the factors responsible for the large losses, emphasizing the hazards peculiar to the occupancy where pertinent.

On the Subject of Dollar Values

In preparing this study and in selecting the fires which should be included every effort has been made to verify the loss figures but they *only* show the general magnitude of the damages sustained. All figures represent an estimate of the actual fire losses with the exception that where available the Association has added figures indicating losses paid due to business interruption. It is unfortunate that means are not available to evaluate this latter type of financial impact on all types of properties sustaining fire losses so that more realistic and consistent loss estimates could be published. Actually, there are so many indirect losses from fires due to interruption of business, destruction of records, deaths, injuries and displacement of personnel that a true estimate of the dollar loss on these 302 fires would be many times the figure given.

The forest fire losses were supplied to the Association from the various regional offices of the U. S. Forest Service.

Principal Occupancy Breakdown

As indicated in the table below there was an increase in the number of large loss fires in all occupancy classes with the exception of habitational. The increase of 27 storage fires and 20 mercantile fires was particularly notable.

Occupancy Class	No. of Fires by Years				
	1951	1950	1949	1948	1947
Manufacturing ..	99	83	67	92	64
Storage	50	23	43	52	45
Mercantile	49	29	26	36	26
Transportation ..	36	31	23	20	22
Habitational	8	11	11	9	6
Miscellaneous ...	60	66	48	59	39
Totals.....	302	243	218	268	202

Geographical Breakdown

Geographically, the greatest number of large loss fires in buildings occurred in New York which had 25; California had 23, Ohio 17, Pennsylvania 12 and Indiana 11. Canada sustained 26 of the major building losses.

Spread of Fires

One increasing figure in this year's record is the number of these fires that spread beyond the building of origin to exposed structures. One out of every four fires involved more than one building! Checking the reasons for this, it was notable that the following factors, either singularly or in combination, were responsible: inferior combustible construction, poorly constructed party walls, ordinary glass windows, interconnecting passageways or conveyors. In 19 cases the fires occurred in congested built-up areas but in 16 other instances, space available for building separation was not utilized.

MANUFACTURING

Abrasive Works

This occupancy, considered relatively non-hazardous, experienced two of the largest losses of the year, one caused by explosion of LP-gas and the other by fire that broke out in an unsprinklered sandpaper drying tunnel in an otherwise sprinklered building. The first of these, occurring on Feb. 8 at St. Paul, Minn., killed 14 workers and was reported in detail in the April 1951 *Quarterly* (p. 305). The second, occurring at Owosso, Mich. on March 17, caused a loss of $1,250,000. In this case, sprinklers operated but were unable to control the fire because of the enormous amount of heat released from the fire in the 40 ft. by 380 ft. plasterboard-on-wood tunnel containing thousands of feet of paper.

Aircraft Engine Test Cell

The explosion which killed eight employees at the Allison plant at Speedway City, Ind. on July 12 was reported in detail in the October 1951 *Quarterly* (p. 95). As a result of this explosion studies are under way to reduce the life hazard in this type of property.

Brick and Tile Works

This occupancy, which from its name might be considered to be immune to serious fires, sustained three losses that aggregated more than $1,250,000 damage. In each instance, wood roofs or wood roof supports, large undivided areas and lack of sprinkler protection were notable factors influencing fire spread. The relatively isolated location of these plants makes for weak water supplies. This latter factor showed up particularly in the Cleveland Builders' Supply Co. fire of July 21 and the Laclede Christy Brick Co. fire (Cannon City, Colo.) Sept. 30.

Chemical Plants

Of the nine large fires in chemical plants in 1951, three occurred in butadiene plants, causing a total loss of $2,800,000. Equipment failures were responsible for two of these. An uncontrolled chemical reaction caused the third. In all three, immediate control was impossible due to the large volumes of flammable vapors released. The Koppers Co. fire at Kobuta, Pa., March 6, was reported in the July 1951 *Quar-*

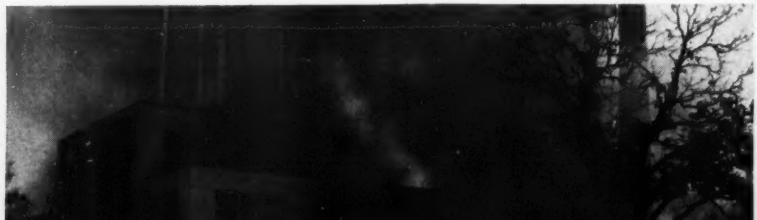
Cleveland Plain Dealer—Ray Matjasic

Large undivided areas, inadequate water supplies and wood construction were factors in the destruction of four brick kilns in this building at the Cleveland Builders Supply Co., Cleveland, Ohio, June 21.

terly (p. 66). An explosion at the Polymer Corp., Sarnia, Ont., May 6, was possibly due to the presence of oxygenated compounds, such as peroxides, in a butadiene separator. Preplanning for emergency at each of these plants was a major factor in preventing extensive damage to other exposed hazardous processes.

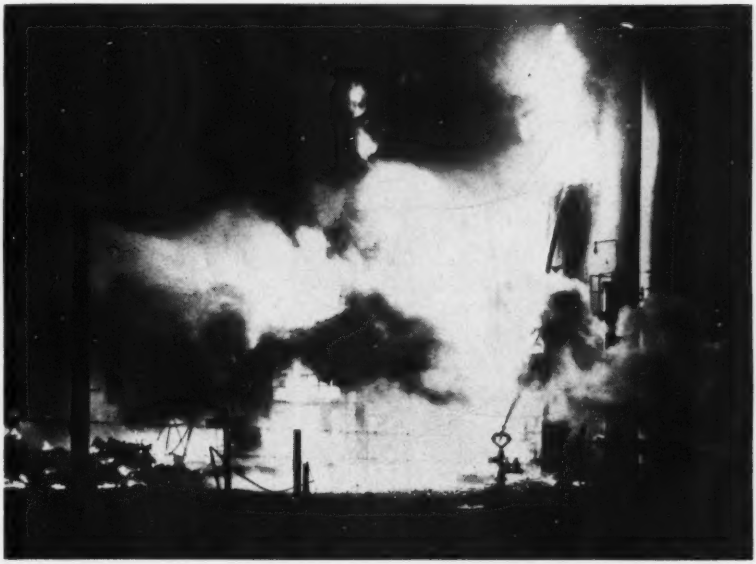
Chemical plants manufacturing lecithin, naval stores, insecticides, and drugs also suffered large loss fires. The inherent hazards of the chemicals handled were responsible for two of these. Three employees were killed in an explosion of pinene vapors at the Panama City, Fla. plant of the American Cyanamid Co., May 4. In this instance an uncontrolled exothermic reaction is believed to have caused boil-over of a reaction tank. Ignition of benzoyl peroxide by friction or heat was the reported cause of fire at the W. A. Cleary Corp., Franklin Twp., N. J., Nov. 18.

In the Panama City fire, as in the Northwestern Chemical Co. fire at West Chicago, Ill., Sept.



Dave Newman

Top hinged explosion relief windows effectively vented the first explosion on Sept. 26 at the Northwestern Chemical Co., West Chicago, Ill. The second explosion, occurring in the basement, caused the severe structural damage.



Wide World

Explosion of a butadiene accumulator, possibly due to the presence of oxygenated compounds in a separator, caused the destruction of other processing equipment, a catalyst warehouse and a fire station at the Polymer Corp., Sarnia, Ont., May 6.

26, violent explosions of flammable vapors damaged fire protection equipment. The West Chicago accident showed the value of explosion pressure relief devices. The first of two explosions at this plant was relieved with relatively minor damage by top hinged explosion window sash. However, flammable liquids found their way into the basement, where a second explosion severely damaged the fire-resistive structure.

A broken glass plug on a 4-inch column was responsible for the $400,000 fire at Kay-Fries Chemicals, Inc., Stony Point, N. Y., June 5. Methyl alcohol was released and ignited.

In seven of the nine fires in chemical plants large quantities of flammable liquids were involved.

Fertilizer Works

Large loss fires in this category occurred in a wet mix fertilizer plant of the Cotton States Fertilizer Co., near Macon, Ga., Aug. 9, and at the Naco Fertilizer Co. plant near Fort Pierce, Fla., Nov. 3. Both unsprinklered plants were located outside city limits in areas not convenient to hydrants and requiring excessively long hose runs by responding city firemen.

Food Products

Ten fires in the food processing industry caused a total loss of $3,500,000. Four occurred in fruit packing or processing plants, all beyond control before discovery by outsiders and all in buildings without watchman or automatic protection. Typical in many respects was the fire at the Taggert Dried Fruit Co., near Hollister, Cal., Jan. 4. When discovered by an outsider at 10:10 P.M. fire was beyond control in the 22,360 sq. ft. wood building. The plant had no private protection and was located in an area without public protection.

Two feed mill fires were similar to the four in fruit packing plants. Here again, fires broke out during the night when discovery was left to the chance of a passerby. Rarely have fires discovered by outsiders been small enough to be readily controlled. At the Nez Perce Roller Mills, Lewiston, Idaho, Sept. 12, it took a vio-

Destruction by fire of the Nez Perce Roller Mills, Lewiston, Idaho on Sept. 12th followed two explosions that are believed to have involved grain dust.

lent explosion (probably grain dust) to get the attention of a passing motorist.

A candy factory, pea cannery, coffee mill and fish packing plant completed the list of large loss fires in food processing plants. Despite the divergency of products processed the stories of the fires at these four plants are identical. In fact the following summary applies to all cases: ten large loss fires in the food processing industry, all in buildings without adequate private fire protection, all occurring when the plants were not operating, and all beyond control when discovered. Other food processing plants should now be amply forewarned.

Fur Works

The one large loss in this occupancy is of particular interest as it highlights a condition that should be investigated by managements of all plants located in areas undergoing major development. Sprinklers were unable to control fire in the third floor of Sable Furs, Ltd., Pointe aux Trembles, Que., Oct. 31 because of inadequate water supply. The supply had been adequate when the system was installed but during recent years erection of a large number of housing developments and industrial plants in this vicinity without increase in water mains had resulted in a gradual worsening of water supplies until they were inadequate for the sprinkler demands.

Jute Bags

Smoking by a prisoner, contrary to prison rules, caused fire that destroyed the jute bag mill at San Quentin, Cal., April 19. With an undivided area of 79,795 sq. ft., 100,000 jute bags and lint covered walls and ceiling, destruction was inevitable.

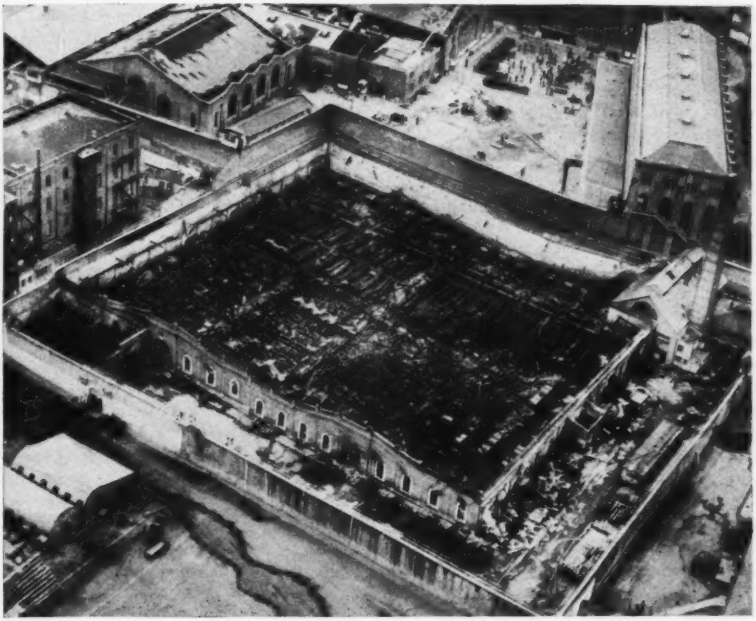
Leather Working

Inadequate water supply was a major factor also in the only large loss leather working fire of 1951. The plant of Ranger Boot and Shoe Mfg. Co., Inc., Terrell, Tex., was located in an area where two weak hose streams were the most that could be obtained from street mains. Consequently, fire involving 50 ft. at one end of the 496-ft.-long factory when firemen arrived could not be prevented from spreading through the undivided structure.

Metalworking

Twenty-seven metalworking plant fires caused $16,343,500 loss in 1951. In reviewing these fires in an attempt to discover how this unfavorable record could be improved, four weaknesses stood out as principally responsible for this bad fire experience in metalworking plants.

Number one is excessive areas. In all except one instance no attempt was made to subdivide fire areas, the average area in 14 plants where



Wide World

In spite of no smoking rules, a cigarette caused the destruction of the 79,795 sq. ft. undivided jute mill and adjacent boiler house at the California State Prison, San Quentin, Calif., April 19.

accurate dimensions were given being 69,000 sq. ft. The one plant in which subdivisions were provided suffered a large loss fire because the fire doors in a division wall were blocked open. This fire occurred at the Hoffman Radio Corp., Los Angeles, Calif. on June 5. Two of five sections of the unsprinklered 76,900 sq. ft. building were badly damaged because fire doors between two sections were open. Unblocked doors functioned properly to prevent spread to two other exposed sections. There were many brick partitions in the unsprinklered 53,500 sq. ft. building occupied by the Spero Electric Corp., Cleveland, Ohio, but openings were not protected. Consequently, fire originating in the paint spray room on Jan. 10 was able to spread to all parts of the building.

Absence of automatic sprinklers shared first place with excessive areas among the predominant fire protection weaknesses in the 27 large loss metalworking plant fires. In 26 cases no sprinkler protection was provided, fire control being left to first aid fire equipment (provided someone was on hand to use it) and to public fire protection (provided someone was on hand to give the alarm). It is reasonable to assume, for example, that sprinklers would have saved the plant of R. M. Price Associates, Inc., destroyed by fire Feb. 26 at Chesterton, Ind. This unsprinklered plant was closed for the weekend and no watchman was on hand to discover fire, call the fire department and use first aid equipment. Fire was through the roof when seen by outsiders.

In more than half of all large loss metalworker fires, flammable liquids were responsible for the inception or spread of fire. Quench tanks, spray booths, dip tanks, oily machinery, drums of oil showed up repeatedly in the fire reports and indicated that flammable liquids is

the most serious special hazard in metalworking plants. It is gratifying to note that flammable hydraulic fluids, responsible for several large loss fires in this occupancy in recent years, were not a factor in the large loss fires of 1951.

Explosive ignition of an accumulation of flammable vapors in the vicinity of a shellac dip tank dislodged the roof and caused fire that destroyed 90 per cent of the building housing the Wells Manufacturing Co., North Liberty, Ind. on Jan. 12. Fire Department warnings to improve ventilation in the paint room had not been followed. On Sept. 15 at Hespeler, Ont. a $345,000 fire occurred at the Hall Foundry Co., Ltd. when sparks from a cutting torch ignited oil-soaked sand on the floor of the core room. The fire spread beyond control while the torch operator tried to extinguish it with sand. It was intensified by explosion of drums of core oil. Other examples from the 1951 large loss record would serve equally well to emphasize the need for protection against the flammable liquid hazard in metalworking plants.

In five fires, employees fought the fire with first aid equipment without success before calling the fire department. The large loss fire record does not, of course, contain examples of the many times that first aid equipment has been successful in putting out incipient fires in metalworking plants. It does, however, point out the fallacy of delaying fire department notification until after first aid equipment has been used. The watchman and employees at the J. I. Case Co., Bettendorf, Iowa are to be commended for their action when fire broke out Jan. 13. Fire was discovered promptly by the watchman, the plant fire brigade and Bettendorf fire department were quickly on the scene and by their combined action were able to confine damage to 15 per cent of the 360,000 sq. ft. undivided and unsprinklered building.

Other factors were evident in the large loss metalworking plant fires but did not appear with such consistency as excessive areas, lack of sprinkler protection, flammable liquids, and delayed fire department notification. Fire at the Ohio National, Inc., plant, Upper Sandusky, Ohio on Jan. 30 caused $2,181,000 damage, the largest metalworking plant loss of the year. It is perhaps more than coincidence that all four of the predominant fire prevention weaknesses of metalworking plants were in evidence at this

Phil Hutchison

Prompt detection by the watchman and good fire fighting by the J. I. Case Co. plant brigade and Bettendorf, Iowa firemen confined damage to 15 percent of this 360,000 sq. ft. building on Jan. 13.

Open pan of paint thinner—friction spark—empty fire extinguisher—undivided and unsprinklered 55,700 sq. ft. ground floor area—single hydrant on 4-inch dead end main—$2,181,000 loss. Ohio National, Inc., Upper Sandusky, Ohio, Jan. 30.

fire. An undivided area of 55,700 sq. ft. was involved. The building was unsprinklered. Cause was ignition of paint thinner by sparks from a grinding wheel. Fire department notification was delayed by employees who were attempting to control the blaze with an empty carbon dioxide extinguisher.

Mining Properties

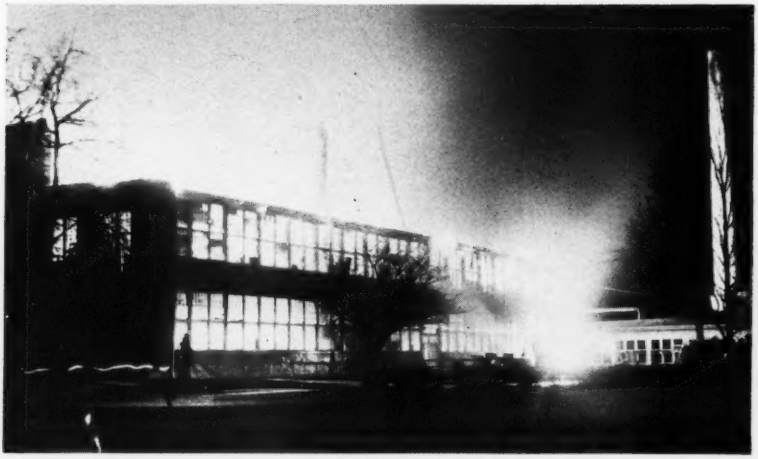
The only large loss fire in mine *surface* property occurred at the uranium ore milling and refining plant of Eldorado Mining Co. Ltd., Port Radium, N. W. T., Nov. 9. Ignition of jute and paper bags by welding sparks was the probable cause. Between six and seven million gallons of water was used by employees to bring the fire under control and protect exposures. (See page 272 for the *subsurface* mine disaster at West Frankfort, Ill.)

Multiple Occupancy

Two of the three fires in this category would not have reached "large loss" proportions if sprinklers had been maintained in operating condition. At Chicago, Ill., Jan. 11, debris in the valve cabinet prevented the ball weight of an old type dry pipe valve from dropping the full limit to open the valve completely. Sprinklers at Patchogue, N. Y. had been shut off during the winter months to prevent freezing. The fire occurred Nov. 20. In a third fire in a multiple occupancy plant, on Sept. 10 in an unsprinklered 9-story building in New York City, arsonists were attempting to set fire to premises of a fifth story tenant when a violent explosion of gasoline vapors occurred, killing three men, setting fire to the building and shattering glass within a 4-block area.

Paper Working

Faulty equipment installed to eliminate flammable liquid hazards was responsible for two of the three fires in paper working plants involving losses in excess of $250,000. A $300,000 explosion April 15 at the Industrial Tape Corp. plant, North Brunswick Twp., N. J., was due to a clogged flammable vapor exhaust duct inlet. Localized overheating of a paraffin dip tank due to a fault in the electrical heating equipment was the probable cause of the $1,005,000 fire at the Cleveland Container Co., Cleveland, Nov. 1. The $502,500 fire suffered by Lesavory Industries, Inc., Newark, Ohio, July 22, was apparently caused by ignition of lint by static electricity at a paper machine. The unsafe practice of storing finished products in the manufacturing area instead of in a cut-off storage area contributed to the size of the loss in two instances.



If fires such as this one at Champaign, Ill. are to be prevented provision must be made to detect them promptly. This fire at the foundry of Alloy Engineering and Casting Co., Inc. on March 10 was beyond control when seen by an outsider at 2:05 A.M.

Plastics Fabricating

The two large loss fires in this class are significant because of the absence of good private fire protection equipment and practices rather than because of special hazards. Fire at the Standard Cap and Molding Co., Baltimore, Md. on Feb. 2 broke out at a press motor in the unsprinklered building. Employees fought the fire with hand extinguishers and did not call the fire department until the blaze had spread beyond control. During the night of Aug. 8 at Sherman-West Hollywood, Cal. fire broke out at the plant of Plastic Process Co., Inc. This building, also, was unsprinklered, and since no watchman or automatic detection was provided, fire was beyond control when seen by outsiders.

Plastics Manufacturing

The one large loss fire in this occupancy (Dow Chemical Co., Midland, Mich., April 6) was believed caused by static spark ignition of flammable vapors. However, lack of sprinklers and subdivisions in the 69,200 sq. ft. building were responsible for the extensive damage. Here again, the storage area was not cut off from the manufacturing area.

Rubber Manufacturing

Fire at the foam rubber processing plant of the Elkins-Ewell Co., Philadelphia, Pa., March 19, originated at a vulcanizing machine. An explosion (reportedly of rubber solvent vapors) blew out front and rear windows shortly after employees fled the rapid spreading fire.

Textile Working

Three of the seven large loss fires in this occupancy class occurred in sprinklered buildings but, because of closed valves prior to outbreak of fire in two instances and premature shut-off in the third, sprinklers were not a positive factor in fire control in any of the seven fires. The premature closing of sprinklers occurred during a fire at the premises of Matador, Inc., in Montreal (May 31), which originated in a sprinklered fibre mixer. Sprinklers knocked the fire down in the mixer and connecting receiving bin but were shut off before fire in the bin had been completely extinguished. Flames broke from the bin and enveloped the 11,200 sq. ft. manufacturing area.

Vegetable Oil Refineries

Special hazards caused two and possibly the third of three large loss fires in vegetable oil extraction plants. At San Francisco, Cal., April 10, an overheated bearing at the bottom of a roto lift conveyor caused a $785,000 fire at the copra oil extraction plant of Cargill, Inc. The same company experienced a $485,000 loss at Cedar Rapids, Iowa, April 29, at their soybean

International

Shortly after firemen arrived at the B. F. McDonald Co. plant, Los Angeles, Cal., unprotected steel roof supports failed and the wood roof collapsed. The fire occurred on Sunday, Dec. 9, and was first reported at 10:53 A.M. by the Los Angeles airport control tower a mile away. Watchman protection on Sundays consisted of two rounds during the day.

Tommeryman

Hexane vapors escaping from a solvent extraction unit at the Cedar Rapids, Iowa plant of Cargill, Inc., on April 29 flowed 125 ft. to a boiler house and ignited. Three buildings were immediately enveloped in flames.

Fire starting in the passageway connecting the top stories of these two buildings swept into both structures and was not controlled before they were destroyed. The fire occurred at the Vaughan-Bassett Furniture Co., Galax, Va., Feb. 27.

oil extraction plant. Trouble at a spent meal plug at the base of extraction equipment allowed hexane to escape. Cause of a $375,000 fire at Planters Cotton Oil Mill, Augusta, Ga., Oct. 26 could not be determined, although an overheated bearing on a seed conveyor was a possibility. At San Francisco no sprinkler protection was provided. At Cedar Rapids deluge sprinklers held down the intensity of fire in the upper portion of the building, but damage to extraction equipment at lower levels was severe due to absence of supplementary water spray equipment. At Augusta, Ga., fire was primarily confined to an unsprinklered conveyor tunnel and did not generate sufficient heat to fuse sprinklers outside the tunnel.

Woodworking Plants

Twenty-one large loss fires occurred in woodworking plants in 1951. Losses aggregated $8,678,000. Responsibility for this destruction belongs to a small group of fire protection weaknesses, well known and common to many woodworking plants. These can be summarized briefly as (1) large areas of combustible construction, (2) poor housekeeping as indicated by dust accumulations on building members and refuse under and around buildings, (3) lack of automatic sprinklers, or substandard protection, (4) disregard of fire prevention safeguards as evidenced by three fires caused by welding sparks and three by sparks from refuse burners, and (5) congested buildings, shown by the fact that nine fires involved more than one building.

Thirteen of the 21 fires occurred in sawmills, three in flooring mills, two in furniture factories and one each in ladder, sash and door, and wood flour mills.

The sawmill, boiler house and drag saw at the High Sierra Saw Mills was destroyed by fire at Hallstead Flats, Cal., June 2. Ignition of sawdust on the framework of an undivided and unsprinklered 10,561 sq. ft. mill by sparks from a refuse burner was the probable cause. Employees' attempts to control the fire with yard hydrant streams were halted when power line meters 22 ft. from the mill were destroyed, stopping fire pumps.

The $716,000 fire at the Vaughan-Bassett Furniture Co., Galax, Va., Feb. 27, was caused by ignition of lacquer residues being removed with a pick and shovel. Two connected buildings of 31,340 sq. ft. and 31,970 sq. ft. ground floor areas were destroyed. Sprinklers were unable to control the fire because of weak water supply, the severe hazard of nitrocellulose resi-

Oregon State Fire Marshal

Dusty undivided wood buildings are susceptible to flash fires such as this one at the sawmill of the Zellner Lumber Co., near Eugene, Ore. on April 21. Before firemen summoned by the watchman arrived, flames spread throughout the mill.

due and dust, absence of a quick opening device, and lack of a fire department hose connection.

Four employees of the Wilner Wood Products Co., South Paris, Me., were killed in a dust explosion at this wood flour mill on Feb. 16. No special provisions had been made to vent explosions in the building and in storage bins.

STORAGE

Agricultural Implements

A New York dock strike forced the Massey-Harris Company to temporarily store a large quantity of farm implements. The location utilized was a large, wood, unsprinklered former drill hall in Brantford, Ontario. On Nov. 9, fire, believed caused by spontaneous ignition of damp wood-flour stored in bags 20 feet high, caused a total loss to the building and a major loss to the valuable implements stored therein.

Builders' Supplies

In five fires in builders' supply warehouses, property valued at over $2,300,000 was destroyed. In analyzing these cases it is interesting to note that two were set by boys playing in the vicinity and two by defective oil stoves. In two cases, also, those on the premises attempted to fight the fire with portable extinguishers, not calling the fire department until it was too late. Two of the fires originated on or adjacent to the loading platforms and spread into the building. Also in two cases there were inadequate public or private water supplies for fire fighting.

Chemicals

Intense fires in storages of hazardous chemicals indicate the particular need for automatic protection of such properties. This was demonstrated in the Harwick Standard Chemical Company fire of May 1, in Akron, Ohio, where firemen were forced to fight the fire with deluge hose streams from the exterior because of fumes and intermittent violent ruptures of barrels containing combustible contents. The 26,500 sq. ft. building stored, among other things, liquid and dry resins in metal barrels and wax in cardboard cartons. On June 4, in South Norfolk, Va., 6,000 tons of sodium nitrate in a 130 ft. by 502

Wm. L. Morgan

Forty minutes after watchman went off duty on Dec. 8, an early morning fire originated in his room on the first floor of an unsprinklered food products warehouse in Monterey, Calif. Fire spread to an adjoining warehouse through unprotected overhead crosswalk.

Richmond News-Leader

A blank wall and lack of ventilating facilities handicapped firemen in controlling a severe fire in this storage furniture warehouse at Richmond, Va. on April 27. Sprinklers ineffective due to poor stock storage arrangement.

Syracuse Herald-Journal

Groceries and anti-freeze were destroyed at Syracuse, N. Y. on July 16 in this food warehouse. No watchman—no sprinkler protection—open elevator shaft.

ft. unsprinklered wood building produced such a hot fire, accompanied by muffled steam explosions, that the entire building was practically destroyed in thirty minutes. The Akron loss is estimated at $664,500, the Norfolk waste at $519,500.

Cotton

About 3,200 bales of cotton were destroyed when about one-half of a 67,000 sq. ft. sprinklered wood-frame, metal clad warehouse was destroyed, in Galveston, Texas, Jan. 31. The wet pipe sprinkler system had been drained due to 17°F. temperatures. The watchman delayed reporting smelling smoke at 10 P.M. until he discovered flames at 11:19. Only effective fire department action saved an adjacent brewery and the rest of the building. This loss is estimated at $833,000, according to insurance advice. In Humboldt, Tenn. on Sept. 14, boys playing among bales of cotton on the loading platform of a Gulf, Mobile and Ohio R. R. warehouse were responsible for a fire that caused a $600,000 loss. While only 137 bales of cotton are reported to have been destroyed other commodities and exposed buildings were involved to bring the loss to this high figure.

Country Grain Elevators

Montana was the scene of $541,000 and $268,000 country grain elevator fires at Billings (Sept. 16) and Medicine Lake (April 27) respectively. Both occurred during early morning hours when the plants were not operating. Both fires were detected by outsiders. Neither building had automatic detection equipment. In neither case was it possible to restrict the fire to the building of origin because of the proximity of exposed combustible structures.

Electrical Equipment (Television Sets)

Near Carrollton, Kentucky, a tobacco sales barn (a skeleton iron clad structure measuring 468 ft. by 190 ft.) was being used during the off-season (early June) to store 1,650 television sets in pasteboard cartons. About 12:50 A.M., a watchman discovered a fire in the television storage area, but the fire was beyond control when the fire department arrived at this location beyond city limits. A $390,000 loss resulted, reflecting the inadvisability of such concentrations of values in unprotected locations.

Food Storage

About 82 per cent of the total of $2,832,000 damages caused by five serious fires in food warehouses during the year was to the food goods themselves. High piling of stock by mechanical handling equipment was a noticeable factor. In four of the five warehouses, no sprinkler protection was afforded while in the fifth, sprinklers were out-of-service as repairs

General view of stove warehouse at West Kankakee, Ill. after it was destroyed by fire on January 1. Fire spread beyond control in unprotected area and overpowered sprinklers in protected area.

had not been completed from a previous serious fire occurring six months earlier. The two most serious fires occurred in California, one near Isleton where three persons were trapped and burned to death after a combustible fibreboard ceiling was believed ignited by sparks from the exhaust of a fork-lift truck. The other occurred at Monterey where a loss of $1,050,000 was sustained after fire spread from the two-story building of origin to an adjacent two-story cannery building through an overhead, enclosed passageway.

Furniture

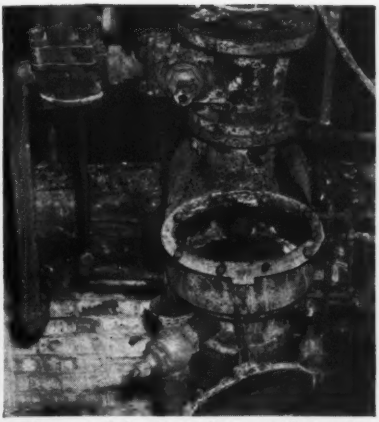
A million dollar fire in Richmond, Va., April 27, a $415,500 fire in Cincinnati, May 22, and a $500,000 loss at Brockville, Ontario, December 19, were examples of serious furniture warehouse blazes during 1951. The Virginia loss was in a 106,000 sq. ft. sprinklered one-story masonry structure where the erection of 6 ft. wide, 3-tier shelves nullified the effective discharge of overhead sprinklers in stocks of mattresses and studio couches. As the fire spread, so many sprinklers opened (1,359 in all) that the available water supply was overtaxed. Fire department hose streams were also not effective due to the shelving, impeded aisleways, and by the fact that the wall nearest the fire had no openings.

General Storage

Gallagher's Warehouse in Philadelphia was entirely involved as fire fighters arrived following a citizen's 12:25 A.M. alarm. Lack of watchman, automatic protection, and enclosures around vertical openings resulted in the total loss of the heavily stocked 4-story building.

Hardware and Appliances

Both of these serious fires involved buildings provided with automatic protection equipment. The serious Florence Stove Company fire in West Kankakee, Illinois, on New Year's Day 1951 caused a $2,000,000 loss of 31,500 crated and cartoned gas ranges, oil stoves and heaters. This terrific concentration of values in a one-



Close-up of dry pipe valve controlling sprinklers in West Kankakee, Ill. plant. Valve was shut off previous to fire.

story 70,000 sq. ft. non-combustible building with a wood roof deck was obviously unwise even with sprinkler protection. Propane gas, leaking from a buried pipe eight feet from the building, followed sprinkler piping into a dry valve sprinkler enclosure and ignited at a heater therein. This valve was closed due to minor repairs to the system. Fire spread overtaxed sprinklers operating in other sections.

At Albany, N. Y., on Oct. 14, the contents of a 3-story building owned by the Woodward Company were heavily damaged. While a central station automatic alarm system summoned the fire department promptly at 4:25 A.M., fire fighters on arrival found the second story heavily charged with smoke. When the area was vented, flames appeared which caused heavy damage to the unsprinklered building.

Machinery Storage

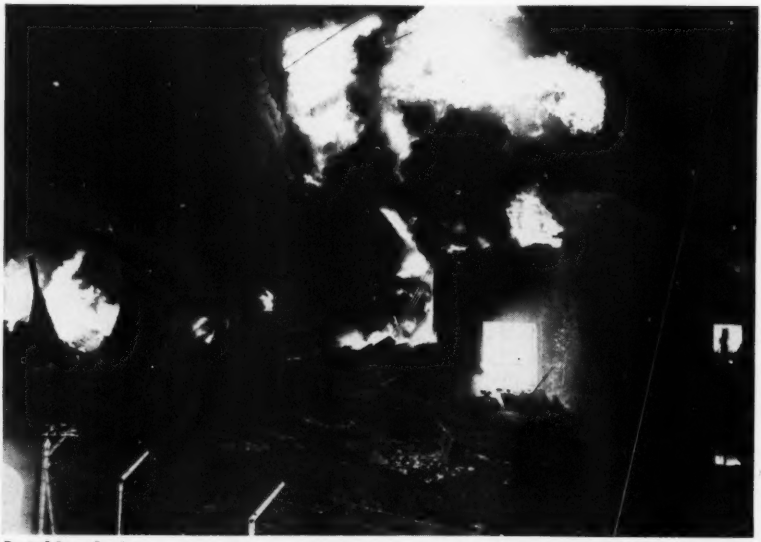
Twenty-seven minutes after a watchman signalled to a central station that all was in order, an off-duty fireman telephoned an alarm from a point three blocks away advising of a major fire in the noncombustible 57,500 sq. ft. unsprinklered warehouse of the U. S. Hoffman Machinery Corp. Contents, consisting of rolls of cloth and padding, laundry and dry cleaning machinery, were heavily damaged before firemen could extinguish the fire five hours later with nine hose lines.

Mercantile Stocks

Fire was neither detected promptly (watchman busy cleaning boilers) nor reported promptly (telephone wires burned) in the 54,750 sq. ft. undivided warehouse of Louis Marx and Company, McMechen, W. Va., on May 15. A million dollar concentration of metal and plastic toys packed in cartons was destroyed as an early morning fire collapsed the 80 per cent all-metal building. Fire fighters from four towns responded to the alarm, but the lack of sprinklers and fire division walls doomed the structure to a total loss.

Acme

Fire department response to the warehouse at McMechen, W. Va., May 15, was delayed as the watchman was busy with other duties (cleaning boilers) and telephone wires burned handicapping alarm transmission.



Capital Press Service

Delayed discovery caused complete destruction of one section of a military warehouse at Ottawa on June 2. A fire wall prevented spread to adjoining sections in the 1,000-ft. by 275-ft. building. U. S. and Canadian military warehouses were damaged to the extent of $3,500,000 by large loss fires.

Military

U. S. Army warehouses at Fort Meade and Voorheesville (N. Y.) and a Canadian Ordnance Depot in Ottawa burned during the year, causing at least a $3,500,000 blow to the defense of democracy. The Fort Meade fire on April 17 was in a 42,760 sq. ft. one-story building protected by a rate-of-rise automatic detection system. Apparently a smoldering fire in clothing had released combustible gases for some time before the detection equipment registered as when doors and windows were opened two mild explosions occurred to completely involve the entire contents. The $2,000,000 fire at the Voorheesville Depot (the third serious fire at this Depot in 6 years) destroyed a 180 ft. x 240 ft. section of a 960 ft. long one-story masonry warehouse which was in process of sprinkler installation. When discovered, the fire involved a tier of crated refrigeration machinery. Just after firemen arrived an explosion occurred and the entire wood roof was involved in a matter of seconds thereafter. Over three-million gallons of water was used to quell the blaze.

The Ottawa fire story is not reported in full detail but the property destroyed was principally a 275 ft. by 175 ft. section of a 1,000 ft. long unsprinklered, brick wood-joist building. This section was used to store large quantities of paints, linseed oil, thinners and other materials, but the exact cause of the fire was not reported.

Multiple Occupancy Warehouses

Five warehouse fires falling into the classification of "multiple occupancy" (more than one tenant owner of goods stored) resulting in an aggregate of $3,650,000 damages are in this year's "large loss" record. None of these buildings had automatic protection.

The North La Salle St., Chicago fire of Jan. 12 (see April 1951 *Quarterly,* p. 313) took the lives of three firemen and one member of the Chicago Fire Insurance Patrol when parts of two walls of the brick, wood-joisted building collapsed early in the fire. This loss, now estimated at $1,245,000 destroyed auto accessories, draperies, bedding, office supplies, food products, etc., owned by various tenants.

In Madison, North Carolina, an old brick wood-joisted tobacco warehouse containing electrical appliances, tractors, fertilizers, and other storages, plus a battery shop (where the fire originated) was destroyed and flames spread to adjoining mercantile property.

In Oakland, Cal., a wood frame metal clad railroad-owned warehouse loaded with potatoes, furniture, household appliances, etc., was prey to a fire on March 24. Railroad tracks made access to the building for fire fighting difficult and water supplies for hose lines were inadequate. Another railroad-owned multiple occupancy warehouse burned in New Orleans, La., on October 31, with a loss of $566,000, and again water supplies at the location were poor. High winds drove flames over the combustible roof covering, around ends of fire walls and over one-foot fire wall parapets.

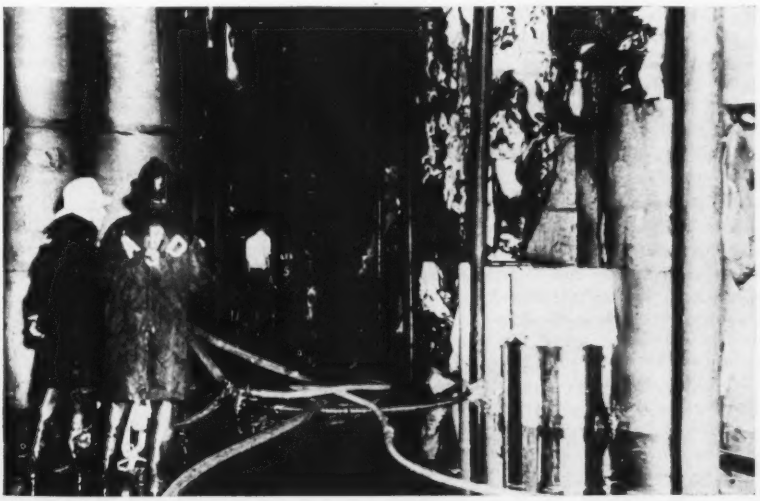
One of the most interesting case histories in manual fire fighting occurred at the multi-tenant warehouse in Parkersburg, W. Va., on July 15. Set by a 15-year-old boy, the fire burned for at least 35 minutes in the 25,000 sq. ft. four-story building before the alarm was given. Good fire fighting with large volume fog nozzles saved a portion of the building containing cylinders of oxygen, acetylene and propane and other storage which had a salvage value of over $25,000. This is one of the first reported instances of the large scale use of water fog in an advanced fire in a multi-storied building.

A $776,000 loss at Horseheads, N. Y., shows that many tenants can suffer in one loss. The Corning Glass Company, the Washburn-Wilson Seed Co. and the U. S. Department of Agriculture had property destroyed in a one-story cinder block, wood roof warehouse, and others might well have suffered had not mutual aid fire fighters responded to a call for help and halted the blaze against a 30 MPH wind which carried flames over 6 ft. parapets.

Multi-tenancy seems to mean multi-hazards, possibly because the building owner does not have control over the goods stored (or doesn't exercise his prerogatives) and, vice versa, the tenants do not control structural fire safeguards.

Paper

The Kodak Park paper storage fire of Nov. 10 is reported in detail elsewhere in this *Quarterly* and was clearly one of the most serious such losses in history. Another rolled paper loss occurred in Alexandria, Va., on August 24.



Alexandria Fire Dept.

Fire on August 24 spread across the tops of paper piled four rolls high without skids at Alexandria, Va. No floor drains or scuppers.

Menominee Herald-Leader

Window openings on second floor which had been bricked up to make building as near hermetically sealed as possible severely handicapped fire fighting in this sugar warehouse fire at Menominee, Mich. on March 24.

Here also high values in one section of an unsprinklered building caused the heavy loss which might have been higher had not automatic detection equipment brought fire fighters promptly, who were thus able to hold the fire to one section of the 45,000 sq. ft. structure. In Marion, Indiana, on June 7, an unsprinklered warehouse containing $299,000 of paper was destroyed as strong winds spread the flames over a wood roof deck having combustible covering. Insurance protection fell over $100,000 short of the actual calculated physical loss. Paper is a critical item in our national economy and proper safeguards are increasingly essential. Fear of water damage due to sprinkler leakage appears unjustified when viewed against the background of such heavy fire losses.

Terminal Warehouses

A lift truck knocked over a salamander in the Falls City Transfer Company warehouse in Jeffersonville, Ind., on Jan. 25. Burning oil from the heater ignited paraffin coated cartons stacked nearby. Employees attempted to fight the fire with extinguishers before calling the fire department. With such odds, the fire department did well to confine the loss to the undivided unsprinklered 300 ft. by 60 ft. terminal warehouse, especially since the exposures were dangerously close on two sides. Another combustible terminal warehouse in Charleston, W. Va., burned with a $392,000 loss but this fire *did* exhibit the value of a brick fire wall with 10 ft. wings on each end since this wall stopped the spread of flames to a communicating section in which cotton valued at $500,000 was stored.

Ammonia cylinders exploding in the Tennyson Transfer and Storage Company warehouse (Boise, Idaho, Sept. 14) handicapped and imperiled fire fighters. The 20,300 sq. ft. undivided, one-story masonry, wood-joisted warehouse was destroyed with the loss estimated at $329,600.

Terminal warehouses demand periodic fire department inspections and owner-fire department cooperation so that fires in such properties containing widely different commodities can be intelligently handled.

Tobacco

Large area combustible tobacco warehouse fires periodically show up in the large loss fire-record and this year two in Kentucky are included. One at Bowling Green on July 20 that

Hutchinson Leader

Fire on April 24 started in an unsprinklered area of a warehouse at Hutchinson, Minn. when sparks from a welding torch ignited paper placed on floor to catch tar drippings.

was set by a 19-year-old boy (previously adjudged an idiot) destroyed $1,050,000 worth of tobacco. The second fire in a sales warehouse at Lexington on Dec. 21 destroyed about $300,000 worth of the leaf. In both cases superior fire department work prevented involvement of serious exposures, but these fires again illustrate the terrific vulnerability of such plants to extremely heavy losses. The taxpayer was hit directly by the first of these because the Commodity Credit Corporation owned two-thirds of the tobacco stored and this much of the loss was thus not "covered" by insurance.

Miscellaneous Other Warehouses

Seven other large loss warehouse fires are on the records. The City of Phœnix sustained a $269,500 loss in a 300 ft. by 300 ft. building enclosing an open compound after sparks from a welding operation ignited a floor sweeping material. The Oklahoma Surplus Property Agency lost $1,265,000 in a fire which destroyed a former hangar filled with Link trainers and trainer parts, medical equipment, radio parts, office furniture, mattresses, stoves, motor vehicles and dismantled aircraft. On Mar. 24, in Menominee, Mich., 41,000 bags (100 lbs.) of sugar, stored in a 28,500 sq. ft. unsprinklered warehouse, were destroyed in a serious fire which took firemen 32 hours to extinguish. The loss in this case ran to $630,000.

In Hutchinson, Minn., a $2,100,000 fire in a warehouse storing adhesive tape (and raw materials for its production) was the second serious loss for a single company within the year. In this building, having 65,000 sq. ft. floor area, sprinklers had been partially dismantled during construction of a refrigerator room. After fire outbreak in this unprotected area from welding sparks, sprinklers in the adjacent area held the flames in check until water supplies were depleted. Building repairs and alterations were thus responsible for another sprinkler "failure" (see also, for instance, the airport terminal building fire at Moncton, N. B., page 271).

Storage practices influence fire safety and the need for more reasoned attention to storage methods was indicated by a fire occurring in Brooklyn, N. Y., on June 13. In this door, sash and millwork warehouse, doors were stacked flat in high piles and the sash in wood racks. Sprinklers, supplied only by a weak water supply (that a pre-fire inspection showed might have cost over $100,000 to correct), were ineffective to combat the flames which entered the structure from a pile of burning rubbish stacked against the metal siding of an exterior wall. Besides this handicap, four sprinklers directly over the point of origin were clogged with stones and mud. By the time the fire department's inch-and-an-eighth nozzles and one deck

Ronald Allen Reilly

Fire wall, with standard protection at all openings and ten-ft. wings at each end, prevented spread to adjoining fire area where $50,000 worth of cotton was stored when fire destroyed a compartment of this waterfront terminal warehouse at Charleston, S. C. on July 12.

gun flooded out the fire, damage reaching $380,000 had occurred.

A warehouse fire (Brooklyn, N. Y., Nov. 26) involved crude rubber. In this case there were no sprinklers and even 22 hose streams and three deluge guns could not keep the blaze from extending to four exposed buildings.

The warehouse fire problem, as illustrated in some of these case histories, often is directly related to the nature of the occupancy. In other cases, the origin is similar to causes found in all types of structures. The fire in Corner Brook, Newfoundland, on December 18, is a final exhibit of how a "common" hazard can be responsible for a $250,000 loss to stored wholesale stocks of tires, beer, cigarettes and other commodities. If the furnace room had only been cut-off from the rest of the building the stock would undoubtedly have been saved. As it was, all was lost, and the fire departments responding had all they could do to protect exposed properties.

MERCANTILE

Conflagration

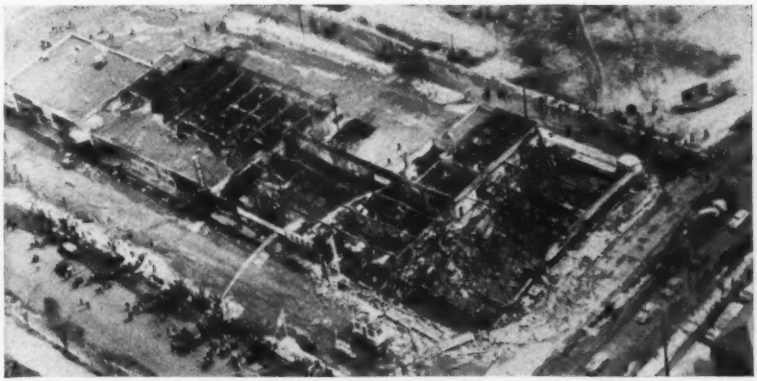
On Jan. 4 fire originating in an unsprinklered department store in Evansville, Ind., destroyed two buildings, severely damaged six and moderately damaged nine. Involvement of exposed buildings was due primarily to absence of protection for windows and doors. A detailed report of this conflagration was published in the April 1951 *Quarterly* (p. 309).

Department Stores

In addition to the Evansville, Ind., conflagration that originated in a department store, there were five other losses in this occupancy, causing approximately $2,000,000 damage. All five occurred in unsprinklered buildings without watchman protection, and in four instances fire had made great headway before detection by outsiders. The fifth fire, Sears-Roebuck Co., Chattanooga, Tenn., Jan. 14, was detected and the alarm transmitted by a central station supervised automatic detection system, but because of the location of the fire in the inaccessible basement, the dense smoke and the windowless walls, fire fighters were unable to control the fire before it spread to the first story of the 4-story fire-resistive building.

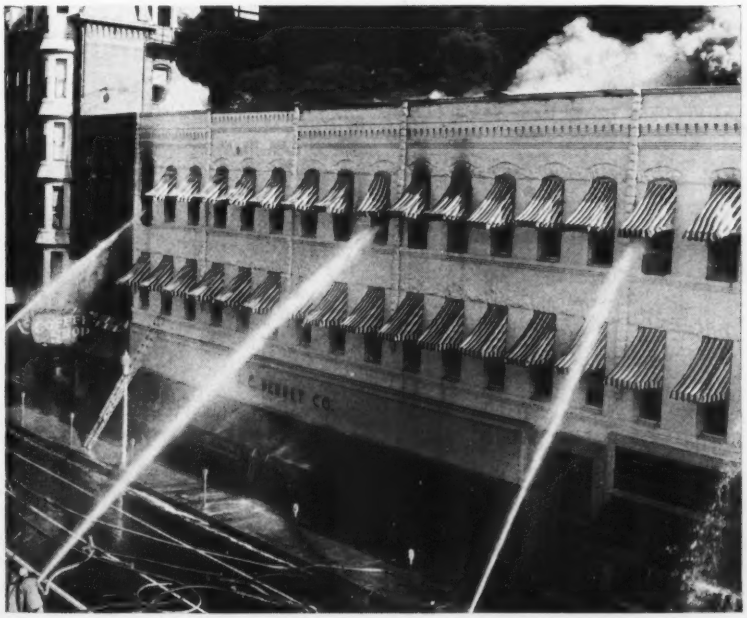
Dry Goods Stores

One of the two large losses in this category originated in the unsprinklered basement, the other above the false ceiling of a first story. Both, however, were not discovered for some time and spread within nonfirestopped walls and above false ceilings. It is also notable that windowless walls (frequently mentioned by fire officials as delaying control of fires in mercantiles) were a serious handicap in both these fires.



Acme Photo

A $1,404,000 fire in St. Paul, Minn., April 1, knocked out this large area shopping center housing 19 mercantile occupancies. Flames were first detected by a passerby at 3:07 A.M. and spread through a fibreboard ceiling to a 2½-ft.-high attic concealed space. There was only one parapeted fire wall (see left corner of photo) in the entire structure.



A dry goods store, variety store and 71 offices housed in this building at Boise, Idaho, were severely damaged by fire Sept. 9. Fire that had apparently been smoldering for some time before detection by an outsider was spread throughout the two upper floors by an explosion of fire gases soon after firemen arrived.

King's Department Store, Newark, Ohio, occupies a fire-resistive building with an open freight elevator shaft and no sprinklers. Fire on Jan. 7 originated on the first floor and went up through the shaft. Loss $408,000.

Furniture Stores

Because of their usually large stocks of combustible contents, furniture stores are particularly susceptible to large loss fires when housed in buildings without sprinklers and watchman protection. Six large loss fires occurred in furniture stores in 1951. All occurred during the night when the stores were closed; all occurred in unsprinklered buildings without watchman protection, and all were out of control when discovered by outsiders. Two large loss furniture store fires occurred in 1950 because of similar deficiencies. It is reasonable to expect that as long as major private fire protection features are omitted from a large number of furniture stores there will continue to be serious fires in this occupancy.

The fire of April 22 at the Crescent Furniture Co., Edmonton, Alta., is typical of the six in 1951 and shows the hopeless situation confronting fire fighters. In this instance fire originated in a packing room in the unsprinklered basement, had filled the building with dense smoke and had spread throughout the undivided basement during the several hours' burning before detection by a passerby at 5:54 A.M. The tragic part of this fire was the death of a fireman attempting to gain entrance to the basement.

Hardware Store

The Baldwin Hardware Co., Tecumseh, Mich., occupied three adjoining 3-story buildings. When fire broke out Jan. 26, open stairways, unprotected openings in party walls and lack of sprinklers allowed the fire to spread throughout the three buildings. Loss was $310,000.

Restaurants

Two large loss restaurant fires occurred in 1951, one in San Jacinto, Cal., Oct. 21, and the other at New Baltimore, N. Y., Oct. 30. The former was beyond control when discovered and spread to five other stores via an undivided attic extending above all six stores in the 1-story building. Ignition of grease left on the kitchen range in the basement was the cause of the New Baltimore fire.

Stores and Apartments

On Feb. 7 at Holly Springs, Miss., fire originated in the store room of a first-story variety store and was beyond control when discovered by occupants of a second story apartment. Fire in a second case (Apr. 19 at Passaic, N. J.), originated in a fifth-story apartment and was coming from the roof when noticed. The third large loss fire in this group occurred at Upper Darby Twp., Pa., Oct. 6. Ten first floor stores and 15 of 16 apartments were damaged by fire that originated in a basement storage room of a first-story drug store.

Supermarkets

The eight large loss supermarket fires in 1951 represent a substantial increase over other years in the number of such fires — two in 1949, one in 1950 — and justify the concern of fire protection engineers for the fire safety of these high value properties.

Although apparently incorporating the most modern equipment and ideas to facilitate large volume retail sales, these stores in many cases are far from ideal in their fire safety features. The most distressing feature of the eight stores visited by large loss fires in 1951 was the failure to provide in any instance fire barrier between the sales area and the storage and food preparation area. Other recurring protection and con-

Los Angeles Times

Lack of a fire wall between the main sales area of this supermarket and the storage area permitted a fire to spread throughout the 20,700 sq. ft. building. Los Angeles fire fighters were faced with a totally involved structure when they responded to the 1:45 P.M. alarm, April 28. Two employees died after being trapped in the area of fire origin.

Redwood City Tribune

An overheated incinerator chimney in contact with wood ceiling and roof supports was the probable cause of fire that destroyed this unsprinklered and undivided 16,725 sq. ft. supermarket at Redwood City, Cal., May 26. Blank walls hindered access for fire fighting.

struction weaknesses noted as influencing extent of damage were absence of sprinklers and watchmen, undivided concealed spaces beneath combustible roofs, and combustible fibreboard ceilings.

Two employees lost their lives attempting to control fire on the mezzanine of Ralph's Market, Los Angeles, Cal., April 29. All patrons escaped safely despite the rapid spread of smoke and fire. However, the adequacy of exit facilities of supermarkets should be a major concern of public officials.

Multiple Occupancy

Six-hundred-and-seventy tenants and sixty-eight buildings suffered total or partial damage in the 18 large loss multiple occupancy fires in 1951. None of the buildings was sprinklered and none had automatic detection or standard watchman protection. The significance of their lack of private protection became evident when it is learned (1) that in all instances fire was beyond control when discovered, (2) that in all except three the premises of origin was closed for the night when fire was discovered and (3) that in all except three, fires occurred between 7 P.M. and 7 A.M.

In multiple occupancy buildings fire prevention and protection suffers because of division of responsibility among multiple interests. Careful attention to these properties is called for by enforcement authorities.

Miscellaneous Other Mercantiles

A combination bar and liquor store at Cordova, Alaska, Oct. 10, a wholesale food merchant at Philadelphia, Oct. 13, and an office equipment store at Saginaw, Mich., Oct. 20, complete the list of large loss mercantile fires.

HABITATIONAL

Apartments

The only large loss fire in buildings used exclusively for apartments (see also stores and apartments, page 266) occurred at York Twp., Ont., Feb. 28. Fire spread from a locker room in the unsprinklered basement up open stairways to upper floors of the 3-story building, cutting off escape of 11 occupants. They were fortunately rescued by fire department ladders.

College Dormitories

The $2,023,500 fire at Mt. St. Vincent College, Rockingham, N. S., Jan. 31, was reported in detail in the April, 1951 *Quarterly* (p. 320). A well-organized, prearranged plan of evacuation was used to remove the 300 girl students and 100 Sisters from the building without injury.

Dwellings

A gas explosion practically demolished the Gus S. Wortham mansion at Houston, Texas, Jan. 31. Because of the fortunate time of occurrence when the mansion was temporarily unoccupied, there were no casualties. Gas was also responsible for the other large loss fire in this category, at Brighton, N. Y., Sept. 21. Explosion of natural gas in a regulator vault broke pressure regulators, allowing natural gas at high pressure to flow through street mains and enter dwellings. Eleven houses exploded and 20 caught fire. Two persons were killed by the explosions and one died of a heart attack. For a detailed report see October 1951 *Quarterly* (p. 85).

Home for Aged, Orphanage

Twenty-eight women inmates and seven women employees lost their lives in fire that swept the 5-story Hospice St. Cunegonde, Montreal, Que., June 15. This was the largest number of fatalities to occur in a building fire in 1951. A detailed report of this fire appears in the July 1951 *Quarterly* (p. 31).

Seasonal Hotels

Two unsprinklered 3-story wood hotels were destroyed in $250,000 fires. At Tamiskaming, Que., a cigarette carelessly discarded during an all-night party in the hotel was the probable cause. All occupants got out safely, but one man who apparently reentered the building lost his life. Destruction of Sherwood Lodge, Lake Placid, N. Y., Oct. 30, occurred when the hotel was closed for the season. Fire was coming from the roof when first seen by a neighbor ½ mile away.

Star Newspaper Service

A carelessly discarded cigarette was the probable cause of this $450,000 fire at the Vaughan Gardens Apartments, York Twp., Ont., Feb. 28. The fire originated in the basement, spread vertically through open stairways.

Year Round Hotels

The Talbot Hotel, St. Thomas, Ont., was the only hotel to suffer a large loss fire in 1951. Fire had apparently been burning for some time in the basement before discovery by the desk clerk and outsiders at 3:15 A.M. When apparatus arrived hallways and stairs were impassable and seven minutes later fire was through the roof of the unsprinklered 3-story brick, wood-joisted building. One man died in his third-story room. Other guests escaped down outside fire escapes and fire department ladders.

TRANSPORTATION

Aircraft

The twenty-nine aircraft fire accidents in 1951 caused 297 fatalities and damage conservatively estimated at $28,850,000.

Students of aircraft fire safety were alarmed by the 12 major aircraft accidents caused by fires or explosions *in flight* during 1951. The military suffered the greatest number of such serious accidents, the B-29's susceptibility being particularly notable. (The number of such losses is influenced by the increased use of this aircraft in continental training and tactical missions.) A total of 143 persons lost their lives in these *fire-in-flight* accidents, but it is significant that 61 others (all military personnel) parachuted to safety from burning aircraft.

The need for adequate airport rescue and fire fighting organizations was again noted. Seven accidents occurred during or immediately after take-off, five during normal landing maneuvres or after touch-down, three while attempting emergency landings and one while on the ground at an airport. Some gains in the provision of airport fire equipment were noted at civilian airports during the year while the military forces received their first production postwar (World War II) crash truck.

In five of these 29 fire accidents, buildings were struck and involved in the damages sustained. The death toll to occupants from these collisions was fortunately light, only in one case were occupants killed. Such accidents as occurred in Elizabeth, N. J., Seattle, Wash. and Denver, Colo., do however raise questions as

The News

This is an unretouched photo (enlarged from a small negative, taken by an amateur) of an engine fire in a non-scheduled airline C-46 over Elizabeth, N. J. on Dec. 17. Wing structural failure followed the uncontrolled engine fire and the heavily loaded aircraft crashed, bringing death to all 56 occupants.

to the location of airports in relation to built-up centers of population and the grouping of housing around the airports themselves.

The twenty-nine accidents reported herein may not be a complete list of the loss by fire of highly valued aircraft because military security is involved in some cases.

Railroads

Forty-six freight cars were burned in a wreck near Halsey, Neb., on June 18, after a defective wheel caused derailment while the train was traveling at approximately 50 MPH. Friction sparks might have ignited spilled crude oil and liquid asphalt from tank cars to start the fire.

Ships

Six major accidents, damaging 9 vessels, killing 62 persons and causing $7,527,500 property damage occurred in North American waters during 1951, excluding vessels damaged or destroyed from fires originating on piers (See Piers and Wharves, page 273. The heaviest loss of life (39 killed) and property damage ($3,032,500) occurred in the Gulf of Mexico, April 20, when the empty *Esso Suez* collided with the *Esso Greensboro* loaded with 141,158 barrels of crude oil. Fire was instantaneous and enveloped both vessels. A Marine Board of Investigation found the masters of both vessels failed to comply with international rules on operation in fog.

Another collision fire accident occurred on Lake Erie on Oct. 29 when a freighter struck a barge loaded with 804,930 gallons of gasoline. Ten were killed, many by drowning, as they were forced overboard to escape the flames.

An engine room explosion killed a chief engineer and an oiler on the tanker M. V. *Transpet,* Oct. 30 in the Gulf of St. Lawrence. The ensuing fire caused the 1605 net ton vessel to sink.

The *Erria,* a Danish motor ship, was swept by fire off Astoria, Ore., on Dec. 20. The report of the USCG Board of Investigation has not been released as of date of publication. Eleven persons lost their lives.

MISCELLANEOUS

Aircraft Hangar

High valued contents in aircraft hangars are chiefly responsible for heavy losses in this type of property. A typical fire occurred in Boston on July 13 when six jet engines and a gunnery trainer were heavily damaged despite effective fire department action in restricting and knocking down the blaze. The loss is estimated at $400,000, ninety per cent to contents.

Airport Terminal Building

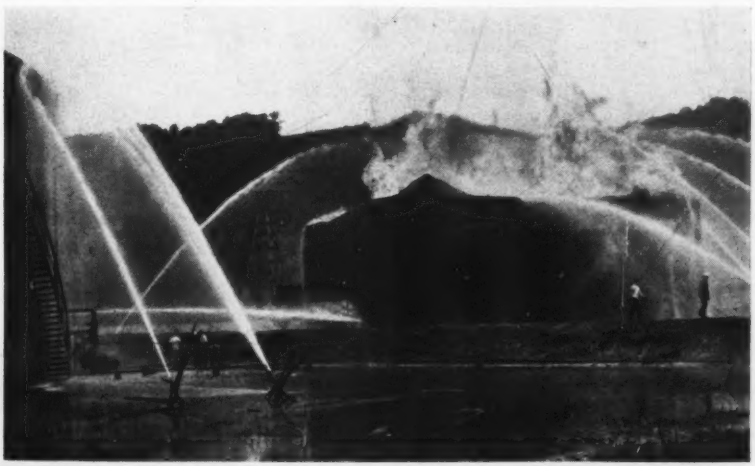
Sprinklers were turned off in a former hangar at Moncton, N. B., while it was being converted to a terminal building. The large area 458 ft. by 224 ft. structure was reduced to ashes, except for a record vault after a plumber ignited combustible structural materials with sparks from a welding torch. Sprinklers were manually operated after detection, but a new second floor shielded the fire from effective roof sprinkler coverage.

Alcohol Storage Tank

Proof that the contents of an all metal welded steel flammable liquid storage tank can be ignited by a lightning stroke was given at the Carbide and Carbon Chemicals Corp.'s alcohol storage tank farm at Institute, W. Va., on July 28. The lightning struck a 2,400,000-gallon storage tank containing over two million gallons of ethyl alcohol. No lightning protection had been provided as the NFPA Lightning Code states that such tanks are inherently self-protected.

Churches

Four of the five "large loss" church fires of 1951, causing an aggregate loss of $1,573,000, broke out while the churches were unoccupied and, for lack of automatic protection, were not discovered until outsiders were attracted to advanced fires in these structures. The fifth fire at St. Joseph's Roman Catholic Church, Pittsburgh, Pa., Feb. 15, was discovered by a choir boy, but was beyond control of portable fire extinguishers and quickly spread from the choir loft to the roof. Concealed spaces within walls and beneath floors plus undivided attic or loft areas were notable contributing factors to the spread of fire in these church losses, substan-



Wide World

Lightning struck a welded steel 2,400,000-gal. storage tank containing over 2,000,000 gals. of ethyl alcohol at the Carbide and Carbon Chemicals Corp., at Institute, W. Va., July 28. An explosion followed immediately which blew the tank roof beyond the dike and spread fire over a considerable area.

Charles R. Conley

This church in Findlay, Ohio was the victim of delayed detection on Dec. 27. The alarm came only after the telephone operator got a consistent busy signal from the church's two phones and notified police.

tiating previous church fire experience. (See NFPA pamphlet, "Churches Are Burning" available from the NFPA Executive Office, $1.00.)

City Club

Combustible decorations, open stairways, ventilating ducts without dampers and lack of sprinklers contributed to the disastrous fire in the Denver Athletic Club on Feb. 17 in which four of the 100 persons in the building died. (See April 1951 *Quarterly*, p. 304.)

Country Clubs

The use of fast burning construction without automatic protection in country clubs, usually located in areas where public protection (particularly water supplies) is weak, produces conditions leading to large losses where the structures are of high value. These factors were emphasized again this year in fires near Littleton, Colo., Feb. 23, in Rye, N. Y., July 27, and at Laval-sur-le-Lac, Que., on Sept. 10. The combined loss of these three fires was $936,500 and in the Littleton fire, which occurred at 5:30 A.M., two occupants asleep on uppers floors lost their lives.

Coal Mine

The largest loss of life disaster of 1951 occurred at the mine in West Frankfort, Ill., on Dec. 21. A violent explosion of methane gas 500 ft. below the surface and two miles from

Fire caused by ignition of lubricating oil escaping under 15 psi from a turbo-generator caused $1,450,000 loss at the Columbus and Southern Ohio Electric Co., near Columbus, Ohio, June 22. The fire burned with such intensity for 45 minutes that steel roof trusses 50 ft. overhead collapsed.

International

A severe fire, followed by a number of explosions of LP-Gas storage tanks occurred at the Warren Petroleum Co's. propane tank farm, Newark, N. J. on July 7. A group of 70 storage tanks (each 70 ft. long and 105 inches diameter) were demolished. One tank landed on a filling station ½ mile away.

the main shaft trapped 119 of the 252 men in the mine.

Electric Generating Station

A loss of $1,450,000 resulted from ignition of oil escaping under 15 lbs. pressure from the lubricating system on a 30,000-KW turbo-generator. The fire burned with such intensity that steel roof trusses 50 ft. overhead collapsed. The interruption to electric power supplied by the Columbus and Southern Ohio Electric Company was a $450,000 part of the insured loss.

Forest Fires

The value of our forest resources can never be properly appreciated, but the need for such appreciation becomes essential by the 1951 large loss fire record. During the year, a mere 16 forest fires caused $19,492,500 in losses and destroyed 247,000 acres of timber land. Five lives were lost fighting these fires. Causes of these fires could not in all cases be determined, although probable cause of 13 were: lightning (5), sparks from railroad trains (4), smoking (3), and sparks from a power saw (1).

Garages

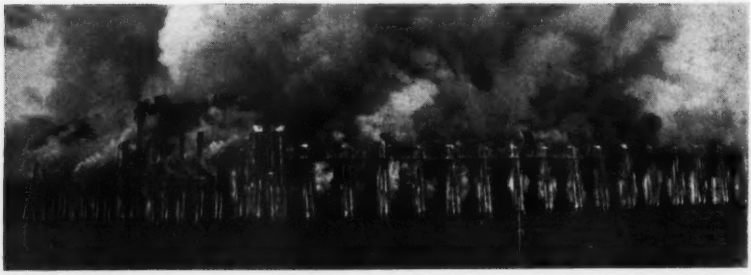
Garage fires are apt to be fast spreading especially where flammable liquids are involved in the inception. Two of the four fires in this year's large loss record originated while employees were repairing or draining motor vehicle fuel tanks. In one, at Charlottetown, P. E. I., a mechanic was trapped in a pit when an electric lamp on a drop cord fell and broke and ignited vapor originating from open buckets of gasoline drained from a truck tank. This fire, before being controlled, destroyed five buildings and damaged five others.

Liquefied Petroleum Gas Terminal

A separate NFPA report on the Newark, N. J. propane terminal fire was published in the July-August 1951 *Fire News* (also available in separate pamphlet form).

Piers and Wharves

Combustible construction, lack of subdivision of superstructures and substructures, absence of fixed protection, the difficult access to such fires by land fire companies and the vulnerability of



Powell River News

Firefighters in Westview, B. C. thought they had this fire under control in the early morning hours of Jan. 27. About this time, however, the flames burned through the pier deck and involved the undivided wood substructure. Final extinguishment took more than 36 hours.

ships lying alongside piers were all made evident in the four large loss pier fires of 1951 which caused an aggregate loss of $12,263,000. The largest single fire loss of the year occurred at a Baltimore pier on Jan. 16. Damage to the pier, a decommissioned 25,000-ton troop transport, a tug, two barges and a floating pile driver totalled $10,300,000. For a detailed report see the April 1951 *Quarterly* (p. 317). While this Baltimore fire originated in the substructure, the pier fires at Westview, B. C. (Jan. 27), Port Reading, N. J. (July 9) and Philadelphia (May 18), all started in pier sheds or aprons. All these piers were of wood construction without subdivision (one was 1,200 ft. long) and without operating sprinklers. In three cases, the fires spread to shipping tied to the piers. In two cases men were drowned attempting to escape the flames. In one case gasoline and oil lines on the pier burned through and intensified the fire.

Public Office Buildings

The need for proper safeguarding of public records was brought home to the Michigan taxpayer in the fire of Feb. 8 in the State Office Building in Lansing. This fire was set by an employee who merely wanted to escape military duty. The resulting $2,850,000 loss was far more severe than what might have been expected because of poor record storage practices. A complete report was published in the April 1951 *Quarterly* (p. 288). Improper record storage was also a vital factor in the Jackson County Court House fire in Jackson, Ohio, on Jan. 25. A large quantity of obsolete records in a 5,000 sq. ft. attic contributed materially to the intensity of the fire. If records are worth keeping they are worth protecting and if they are obsolete they should be destroyed by less costly means.

Petroleum Production and Distribution

Four large loss fires originating in petroleum production and distribution plants caused an aggregate loss of $5,817,500. Included herein is the Kansas City flood fire of July 13, which started when flood waters floated gasoline storage tanks from their foundations. One large tank struck a high tension wire, caught fire and exploded. Burning gasoline spreading over the water ignited practically all property in a 215-acre area, including three tank farms, two large lumber yards and numerous buildings housing small industrial plants.

The other large loss petroleum fires occurred at Los Angeles, Cal., July 12, Baton Rouge, La., Aug. 16 and Trenton, Mich., December 5. In these three cases, fire damage was confined to refinery property, although in the Baton Rouge incident explosion damage was sustained by glass within the city.

Schools

Just why it is that sprinkler protection is shunned by schools is difficult to understand. Certainly, no greater evidence of its value is needed than a review of the seven large loss school fires in this year's record (causing a total of $3,239,500 loss). In each of these cases, fires had progressed beyond control before discovery, in fact, in six out of seven, outsiders were the first to detect flames in the unsprinklered buildings involved. None had automatic detection or standard watchman service. In the one case where

Acme

A static spark during blending of butane into gasoline in a tank containing 31,000 barrels of the latter was the probable cause of this refinery fire in Los Angeles, Calif., July 12. Three diked areas were involved before the 50-hour job of fire fighting was completed.

At Kansas City, Mo., July 13, practically all property in a 215-acre area was destroyed by fire that broke out while the area was under 9 ft. of flood water. The fire started at a tank farm when flood water floated a gasoline storage tank from its foundation.

Large loss school fires usually occur in unsprinklered buildings when no one is around to discover the fires when still small. This was the case at the high school fire at Edwardsport, Ind., Nov. 10, shown in this picture.

children were in the building (Lawrence, Mass., Mar. 30), previous school fire drills paid-off and all were safely evacuated.

Shipyards

Large areas of combustible construction without adequate fire breaks were common factors in an East Coast and a West Coast Shipyard when each suffered $500,000 fire losses last July and August. In one case (New York's City Island), the origin was an explosion on a 58 ft. yacht undergoing fuel tank repairs. High winds spread the blaze in the congested area to involve five wood sheds and one brick wood-joist building. Five other yachts were also destroyed. In the West Coast fire (Tacoma, Aug. 24) fire was first discovered by an outsider at 2:03 A.M. and within seven minutes of the alarm had spread throughout the 150,000 sq. ft. construction yard.

Other Properties

Seven other individual properties sustained large loss fires during 1951. The largest single loss occurred Jan. 15 at Anchorage when a 49,500 sq. ft. railroad repair shop was swept by flames as firemen were handicapped by frozen hydrants and the lack of radio alarm facilities to call for help.

On April 27 a newspaper printing plant in Sioux Falls was heavily damaged by a fire originating in a waste paper storage room in the basement and the watchman delayed pulling a private fire alarm box until the wires had burned, rendering the system inoperative.

A lumber yard fire in Philadelphia on Aug. 28 took 30 hose streams to control. The fire, estimated as causing $709,500 damage, was apparently set by 3 boys.

In a Milwaukee laundry on Nov. 20 a gas explosion, occurring during attempted ignition of a gas fired heater for driers, was followed by a fire that caused $250,000 damage before being controlled. Fire spread to the second story through a conveyor.

Collision of a gasoline tank truck with another truck in the middle of a 300 ft. long steel framed bridge, resulted in a serious loss near Kentland, Ind., on Nov. 29. The tractor semi-trailer, having a capacity of 6,000 gallons, burned and the heat collapsed the steel bridge supports. The trapped truck driver was burned to death.

Use of an incinerator after the vent flue had been removed was believed responsible for a fire in a New Orleans gymnasium on Dec. 13.

Ninety file cabinets of records were lost in the Akers Motor Lines office building near Gastonia, N. C. on Dec. 16.

FACTORS IN THE LARGE LOSS BUILDING FIRES

Location of Property

Just as many large loss structural fires occurred in towns of less than 20,000 population (or in unincorporated areas) as in the larger cities of 20,000 or over. The record therefore shows it's not where you live but how you live! A breakdown by major occupancies shows that while about 60 per cent of the manufacturing plant losses were in the smaller towns, about 60 per cent of the mercantile and storage fires occurred in the larger cities. Industry which moves beyond city limits must provide commensurate full scale exterior and interior fire protection. Those within city protection zones must also incorporate interior fire detection and protection equipment if they care to safeguard high values of stock and storage properly. Ten per cent of all the large loss building fires occurred in unprotected areas.

Construction (Basic Types)

Half of the large loss building fires occurred in brick wood-joist buildings, about a third in wood or wood frame, metal clad buildings, 9 per cent in noncombustible or heavy timber and 3 per cent in fire-resistive. As would be expected, 77 per cent of the mercantile occupancies were housed in the brick wood-joist buildings, the conventional older type construction found in American built-up city areas.

Although it is recognized that the combustibility of the contents is a vital factor in the seriousness of a fire in buildings of any construction, this record does show the inherent vulnerability of buildings having combustible structural elements.

Operating Status

When properties are idle, fires seem to be busiest. In the record this year approximately 70 per cent of the large loss structural fires occurred while the property was either not in operation or only in partial usage.

The natural "lessons" from this experience point to the validity of the claim that automatic protection is essential. In properties not so protected efficient, well-trained, intelligent watchman service following NFPA recommendations (Pamphlet No. 601) is needed.

Detection

Each year outsiders are most frequently the first to discover the fires which develop into large losses. This year, 44 per cent of all alarms were given by passers-by. There are, however, significant variations among the broad occupancies as shown by the 80 per cent detection by outsiders in mercantiles, contrasted with the 33 per cent in manufacturing.

The reasons, of course, for the greater employee detection of incipient fires in manufacturing plants are (1) longer working hours and (2) more fires caused by operating hazards. It follows that knowledge of what to do in case of fire is particularly important in industrial occupancies. Procedures for calling the fire department, assembling the fire brigade and using fixed and portable fire appliances should be prearranged.

Watchmen were the first to detect 10 per cent of these serious fires. In 21 instances, however, watchmen failed to detect the fires promptly. In 7 instances watchmen fought the fire before giving the alarm.

Time of Alarm

Repeating a consistent trend, 58 per cent of the 251 large structural fires were initially reported during hours of darkness. Stores closed for the night were visited by 77 per cent of their fires during such shutdowns. Industrials experienced an increase

in night-time losses (63 per cent), presumably because of longer around-the-clock working hours. The serious warehouse fires were pretty evenly distributed during the day and night, indicating that their vulnerability is not so greatly affected by their operations.

Alarm Transmission

The reliance placed on the telephone for alarm transmission was reemphasized by the study of the 1951 large loss fire record. Two-thirds of all the alarms were reported by this means as contrasted with only 18 per cent reported by street fire alarm boxes, 6 per cent by private boxes, 6 per cent by persons running to fire stations, 3 per cent by automatic equipment and 2 per cent by police radio.

The eight cases where telephone wires were burned prior to their attempted use and the three cases where telephones were made inaccessible by fire spread indicate some of the limitations in the use of this equipment for alarm purposes. The telephone, of course, is frequently the most convenient (and quickest), and sometimes the only method of alarm transmission. Where such dependence is placed on the telephone, attention should be given to protecting circuits and locating instruments so that they will be safeguarded from early fire damage.

Causes

Research on fire causes is most difficult in the large loss fire experience since so many of these fires are beyond control when discovered and evidence of fire origin is destroyed. In 91 cases causes were determined with reasonable accuracy. In 43 of these the hazard was considered "special" to the occupancy, while in 37, a "common" hazard was involved. A five per cent increase in the number of incendiary or suspicious fires was noted in the 1951 record as compared with 1950.

Private Automatic Protection Weakness

Twenty-five large loss fires and explosions occurred in sprinklered properties, resulting in $18,811,000 damages, an average of $752,440 per fire. This unfortunate record is, of course, influenced by the high value of sprinklered properties, but the lessons the fires teach should receive very careful attention by all concerned.

Closed valves were the number one offender. In 5 instances unsupervised valves were shut off due to alterations or repairs to the sprinkler system. Three valves were closed to prevent freezing and three were shut for undetermined reasons. At one plant, in Montreal, Que., sprinklers operated satisfactorily but were prematurely shut off only to result in the fire spreading beyond control. Sprinklers cannot be expected to prevent large loss fires if they are not maintained in operating condition.

Four explosions in 1951 so damaged sprinkler equipments that their value to the buildings protected was nullified. The blasts also killed 7 employees, 4 in the Wilner Wood Products plant, South Paris, Me., Feb. 16 and 3 at the American Cyanamid Co.'s plant at Panama City, Fla., May 4. In one additional case, the hazard of the occupancy was judged too severe to permit the ordinary type sprinkler system installed to function effectively.

Inadequate water supplies for sprinklers accounted for three "failures." These were all single source systems depending on public water main supplies which, in the crucial test, were found to be inadequate to supply the demand of the protective devices. In two of the three cases, gravity tanks, constituting a second source of water supply, had been discontinued.

High and otherwise improperly piled stock rendered sprinklers ineffective in fires at the Federal Millwork Corp. builders supply warehouse in Brooklyn, N. Y., and at the Miller and Rhoades furniture warehouse at Richmond, Va. In both cases sprinklers operated, but their discharge was ineffective due to rack and horizontal storage of large combustible commodities shielded from direct water application.

In one abrasive and one tile plant the provision of only partial sprinkler protec-

tion accounted for two other large loss fires. In both cases the fires originated in unsprinklered areas and the losses must be attributed to the failure of the owners to provide the full protection required. One ancient dry pipe valve failed to operate properly in a Chicago tenant manufacturing building which sustained a $733,000 loss as sprinklers were denied water.

Four large loss fires occurred in properties protected by automatic detection equipment. All systems functioned to summon fire departments, but for one reason or another, effective manual fire fighting could not be accomplished in time to prevent these heavy losses, aggregating $1,499,500. In at least two cases evidence is quite conclusive that smoldering fires did not generate heat at a sufficient rate to activate promptly the installed rate-of-rise protection systems.

Other private protection weaknesses showed up, particularly the lack of well-organized fire brigades, suitable special extinguishing systems for special hazards and the lack of portable fire extinguishers. In 35 cases, it is judged that the fires were too advanced when discovered for effective use of portable extinguishers.

Character of Contents Influencing Spread

In 58 fires flammable liquids were involved to intensify the rate and spread of fire in these "large loss" disasters. Flammable liquids were released during these fires from drums, cans, etc. (32 cases), from industrial devices (13 cases), from above ground tanks (8 cases) and from pipe lines (6 cases). In 42 cases the flash point of these liquids was below 80°F.

Heavy concentrations of combustible stocks in single fire areas, poor stock subdivision and high piling were notable factors in a large number of cases. Poor housekeeping conditions, including heavy accumulations of dusts on beams, girders, etc. influenced fire spread markedly in a total of 23 cases.

Structural Characteristics Influencing Spread

In 60 per cent of the "large loss" building fires failure to subdivide areas to reasonable dimensions permitted the fire to reach "large loss" proportions. In 68 per cent of the building fires, unenclosed stair or elevator shafts were responsible for multi-story fires. Among other structural weaknesses noted were: large undivided attics (14 fires), combustible fibreboard interior finish (8 fires), nonfirestopped concealed ceiling spaces (5 fires), large undivided basements (4 fires), and lack of dampers in air conditioning ducts (4 fires).

Windowless buildings and blank walls restricted freedom of fire department access to burning interiors in 12 fires. Lack of basement entry denied access in two instances. Lack of venting facilities handicapped firemen in six cases. Property owners, particularly those who do not provide adequate private fire protection, should be made to appreciate, before it is too late, the access requirements of fire departments answering their calls for help.

Fire Department Activities

There may be a tendency on the part of the uninformed to place major responsibility for "large loss" fires on the fire department. However, when it is remembered that a large percentage of these fires were beyond control when discovered, that many of the properties were located in areas where water supplies from hydrants were weak or nonexistent, and that in other instances fire departments established for small town or rural protection were all that were available, there is little justification for blaming public fire departments for these fires.

In 43 per cent of the fires extent of fire on arrival forced the fire department to concentrate on protecting exposures. Forty explosions preceding, at the start and during the fire complicated fire department operations, as did heavy smoke conditions in 17 cases.

Fire Gas Research Report

Report of Research by Arthur D. Little, Inc.

presented by

NFPA Committee on Fire Gas Research

JOHN L. WILDS, *Chairman*
Protection Mutual Fire Insurance Co., 231 South LaSalle St., Chicago

M. M. BRAIDECH
National Board of Fire Underwriters

BRAHNA C. HUTCHINS
Safety Research Institute

FRANK MURPHY*
New York City Fire Department

DR. C. M. PETERSON
American Medical Association

DR. H. H. SCHRENK
Industrial Hygiene Foundation of America

ALVAH SMALL*
Underwriters' Laboratories, Inc.

*Messrs. Murphy and Small had both retired prior to the completion of this report but were active in the initial committee project.

CONTENTS

	Page
The Effect of Exposure to Heat	282
Systemic Effects of Hyperthermia	284
Classification of Burns	286
Tolerance of Living Tissues for Heat	287
Effect of Inhaling Heated Air	287
Effect of Oxygen Lack	288
Causes of Deaths in Fires	289
Pathological Finding in the Respiratory Tract after Heat Exposure	291
Carbon Monoxide and Carbon Dioxide	292
Specific Gas and Vapor Hazards	294
Comparison of Carbon Monoxide and Hydrogen Sulfide	294
Irritant Gases	294
Sulfur Dioxide	296
Nitrogen Oxides	296
Cyanides	297
Refrigerants	297
Carbon Disulfide	298
Miscellaneous Gases	298
Chemical Action and Structure	299
Emergency Treatment	299
Appendix	300
The Structure of Skin	300
Structure of Respiratory Tract	301
Tables: Comparable Effects of Gases	302
References	305

Fire Gas Research Report

Introductory Statement by Committee

The large number of fire casualties from the inhalation of noxious products of combustion, as distinguished from burns sustained in fires, has long been of most serious concern to the fire protection fraternity. While the danger from flame is obvious and instinctively avoided, the dangers from breathing smoke, gases produced in fires, and oxygen deficient atmospheres are often not apparent.

Some phases of this general subject have been a matter of common knowledge in the fire service, but there has been a long-felt need for more exact technical information on fire gases, the conditions of their formation in fires, their effects singly and in combination, and the most effective means for minimizing their hazard to the lives of occupants of buildings and fire service personnel. In recognition of this need, the National Fire Protection Association in 1940 initiated a project for research on fire gases and subsequently received contributions to form this project. The war period delayed the initiation of the research, but also yielded additional experience records in wartime fires and incendiary warfare.

The Committee on Fire Gas Research, which was charged by the NFPA Board of Directors with the responsibility for administering this project, in 1947 concluded arrangements with Arthur D. Little, Inc., consulting chemists and engineers of Cambridge, Mass., to conduct the research. This organization was selected because members of the staff had participated in wartime research projects of the Federal government concerned with fires and fire gases. It was originally hoped that clearance might be obtained to make publication of the resulting data possible. When it was apparent that such clearance could not be obtained, the objective of the project was altered to cover a survey and evaluation of information obtainable from other sources. This, it was planned, could form the basis for experimental research at such future time as sufficient funds become available for the purpose.

A report was submitted to the Committee on Fire Gas Research by Arthur D. Little, Inc. in 1949. The material in this report has been edited to conform to the NFPA policy for publications sponsored by them and to make the material more useful to the fire protection fraternity. The report is presented herewith by the Committee on Fire Gas Research. Some controversial material contained in the report submitted by Arthur D. Little, Inc. has been omitted by direction of the Committee and the editorial changes are those intended to make the terminology and method of presentation consistent with fire protection practice.

The Committee fully appreciates the need for further research in this field and hopes that a more complete body of technical information on fire gases may eventually be developed in the interest of reducing loss of life and personal injury by fire.

The Effect of Exposure to Heat

The systematic disturbances caused by the impact of heat energy on the surface of the body was an important cause of disability and death in World War II. This led to a recognition of the importance of knowing the thermal tolerance of living tissues and the nature of somatic and cellular changes induced by hyperthermia. (This latter term is used to indicate an increase of general body temperature above the normal level of 98.6°F or 37°C.) Hyperthermia, if sufficiently elevated, leads to irreversible cellular injury. There is a reciprocal relationship of time and temperature in the production of either systemic or cutaneous injury by heat. An additional relationship exists between the environmental or ambient heat, surface temperature, the thermal gradient through the skin, the pathogenesis of cutaneous burns and the physiological mechanisms by which external heat may be responsible for acute disability or death.

Thermal injury may be due to flame, to hot air, to superheated combustion products, or to live steam (above 212°F). When actual burning is limited or absent, hyperthermia may cause damage to the cardio-regulatory centers of the brain and produce such rapid organization of ventricular fibrillation that death is immediate. This is probably what happens in flash fires where excessively high ambient temperatures are produced for extremely short periods (*i.e.*, 0.1-1.0 second). Approximately 3 cal./sq.cm./minute can be absorbed by unprotected human skin. However, heat can be lost by the vaporization of surface moisture at the rate of 1 cal./sq.cm./minute. Man's threshold to cutaneous injury may be between 1 and 2 cal./sq.cm./minute.

The experimental investigation of the causes of injury and death resulting from fires meets such complex phenomena that absolute answers are not possible. Certain factual observations can be recorded but the understanding of the physiological mechanisms and structures involved is, in many cases, a matter only of conjecture. The understanding of causes and relationships is of utmost importance in relation to protection from injury, prevention of death, or treatment of persons who suffer injury and disabilities.

The variables which are common to all conflagrations are few; it is only by experimental and controlled studies (which eventually lose their academic features) that discreet bits of information can be fitted into a pattern. Some of the variables are chemical, others are physical and as in all investigations involving living persons or animals the factors of individual resistance and susceptibility complicate the picture to an infinite degree.

The chief physical variable which is related to the production of injury is intensity of heat. This may exist in a wet or dry atmosphere and the damage done will be modified accordingly. The proximity of the source of heat to exposed subjects, the maximum temperature attained, the ventilation and oxygen supply, the accumulation of carbon dioxide, the presence of carbon monoxide and other toxic gases will similarly affect the extent of injury which may be sustained. Protection against these factors can be afforded in a variety of ways

but not any is completely adequate. Protective clothing masks and general psychological, physiological and constitutional resistance including ability to sweat and range of tolerance of the cardio-vascular system are prominent among the factors which may limit injury or prevent death.

The studies of Dr. Alan R. Moritz and his associates of Harvard Medical School which have been published since 1945 are the best source of information at our command in reviewing this problem. The work of Moritz et al arose from the need for such information by the Armed Forces during World War II and their experimental work utilized animals of various species.

In general, exposure was to various types and intensities of heat under controlled conditions. The routes of exposure were either by inhalation of superheated air (either dry or moist) or by exposure of the body surface (cutaneous). In some cases, exposure was of both types. The effects noted were either local or superficial injuries or those affecting the entire body and developing only when the general temperature of the body was raised. As a result of mathematical analysis of some of Moritz' data, it is possible to predict the probability and extent of injury to the body surface for various temperature ranges.

The physical laws which relate to heat transfer are of great importance in relation to the passage of heat through the skin at different skin temperatures. The effect of different rates of heat transfer on the subsurface temperature gradient of the skin are not greatly different than through other materials of the same density, consistency and general type. There is a modifying factor which operates as a cooling and therefore a limiting mechanism, *i.e.*, the blood vessels of several diameters with which the skin is well supplied and which serve to carry away from the area a surprisingly large quantum of heat. In fact, this is a function of blood which is too little appreciated in the light of its importance in the maintenance of temperature constancy of the entire body.

One disadvantage inherent in all experimental physiology related to heat transfer lies in the fact that no readily available experimental animal has sweat glands which resemble those of man and which facilitate heat loss by vaporization. For example, man can lose approximately one liter of fluid per hour via the skin under extreme conditions and this results in dissipation of 0.5-1.0 calories per square centimeter per minute. The animal whose skin resembles that of man most closely in reaction to heat is the young domestic pig yet the maximum heat loss by vaporization at the body surface is of the order of 0.1 calories per square centimeter per minute or approximately one-fifth to one-tenth that of man. The thickness, cellular structure and blood supply of the young pig's skin is comparable to that of man and for that reason, the species has often been used as a test animal in experimental work related to heat.

The heat capacity of porcine skin (the amount of heat needed to raise the temperature of 1 gram by 1°C) is about 0.7 calory. For comparison, the heat capacity of water is 1.0 calory/gram/degree centigrade and that of metallic silver is .06 calory/gram/degree. This figure is the average of the heat capacities of the components of skin, *i.e.*, epidermis, dermis, fat and muscle. (See Appendix for detailed description of skin structure.)

The conductivity of skin or the rate of heat transfer determines the degree to which the skin will be burned by the application of heat. If the heat can be rapidly carried from a given site, burning will be less than if insulating factors hold it there. This shows the essential relationship between duration of exposure and intensity of heat. Such a factor is not easy to determine except under artificial conditions but *in vitro* determinations show the general relationship.

Immediately after exposure to heat the body surface becomes "heat-saturated" following which the rise in local temperature is slower. The secondary response to heat by the body surface is the accumulation of body fluids between dermis and epidermis, *i.e.*, "blistering." The fluids tend to slow down heat absorption.

Heat from burning material can be conveyed to the body surface by air conduction, air convection or by infra-red radiation. The rate of transfer through air is much more rapid than through the skin itself. It has been maintained that the release of toxic breakdown products after burns which terminate fatally may be the cause of death. The evidence to support this is of a contradictory nature and the concept does not seem to be well substantiated.

Systemic Effects of Hyperthermia

The exposure of the body surface to excessive heat may cause rapid circulatory failure and death. This is brought about by two mechanisms. In one, the systemic hyperthermia caused by conduction of heat to the interior of the body via the blood stream leads to a rapid and progressive decline in blood pressure and failure of circulation due principally to peripheral vascular collapse. In the other, circulatory failure is chiefly caused by changes in the central nervous system and may be due to the effect of an excessively high blood plasma-potassium concentration on the heart. Circulatory failure originating in the central nervous system is likely to occur when overheating of skin and subcutaneous tissues is so intense, prolonged and generalized that potassium is released from the red blood cells rapidly and in such large amounts as to result in maintained plasma levels in excess of 11 milliequivalents of potassium per liter of blood.

In cases of thermal exposures of low intensity, peripheral circulatory failure may occur without sufficient rise in tissue and blood temperature to cause a dangerous rise in plasma potassium. When the thermal exposure has been sufficiently severe to cause fatal hyperpotassemia, the central circulatory effects are likely to be complicated by peripheral vascular collapse. Before potassium poisoning following exposure to heat can occur, the red blood cells must have a high original concentration of this element. Thus, fatal hyperpotassemia can not occur in the dog which normally has a low basal potassium level. Man and pig have a similar blood potassium level and so are similarly susceptible to the development of fatal levels in the blood. Although thermal exposure may alter respiration, death may occur in spite of artificial respiration and this treatment does not prolong the survival period after exposure to heat.

Thus, failure of the heart induced by an accumulation of potassium from overheated red blood cells may produce death; the secondary mechanism is a systemic effect caused by conduction of heat to the interior of the body producing initially peripheral vascular collapse which eventu-

ally affects the heart after loss of fluid in the capillary beds. This does not occur unless the peripheral vessels are greatly dilated.

In summary, the systemic disturbances noted in experimental hyperthermia include:

(1) An increase in rectal and blood temperatures although these are not as persistent as during sunstroke in human subjects.

(2) Intravascular hemolysis but this is not the determining factor in survival since it is not seen in death from hyperthermia following low intensity exposures.

(3) The blood, following high intensity exposure, shows microcytosis and breakdown of red blood cells.

(4) An increase in clotting time and fragility of red cells in badly burned subjects.

(5) An increase in plasma turbidity together with formation of agglomerates of protein and enmeshed cells in wet blood smears (seen in fatally burned animals).

(6) A rise in blood pressure and respiratory rates within a few seconds of exposure. The blood pressure then falls to subnormal levels but the respiration remains rapid until after the exposure ceases.

(7) There are abnormalities of the electrocardiogram some appearing soon after the beginning of the exposure and some developing after the onset of circulatory failure. These include increased rate, decreased voltage of the QRS complex, inverted T wave and ventricular extrasystoles. Ventricular tachycardia, fibrillation and death occur after long exposure.

(8) The blood potassium concentration is increased and may be 4-6 times the normal level. This suggests the possibility of acute potassium poisoning as a cause of death.

(9) Pathological findings include skin burns, subendocardial hemorrhage and degenerative changes in the liver and adrenal cortex.

Two animal experiments of Dutra and Moritz may be cited to demonstrate the relative effects of heat and carbon monoxide and their relative lethality. In the first experiment, a young pig was exposed to burning gasoline in a sealed chamber. The fire was smothered in 30 seconds, but the pig was exposed for five additional minutes. The maximum temperature attained was 320°C or 608°F. Immediately after the fire burned out the atmosphere breathed by the animal contained 15.5 percent oxygen, 3.9 percent carbon dioxide, 0.8 percent carbon monoxide.

In contrast, the expired air contained 16.3 percent oxygen, 4.0 percent carbon dioxide; the alveolar air contained 14.2 percent oxygen, 5.5 percent carbon monoxide. Normal expired air contains 19.7 percent oxygen, 0.8 percent carbon dioxide. The pig's blood was 33 percent saturated with carbon monoxide. When sacrificed 6 hours later, no pathological changes were found in the respiratory system.

In the second experiment, a pig of approximately the same size and age was exposed 40 seconds to the combustion of gasoline which raised the temperature to 300°C. Death occurred in 2 minutes. The blood was only 8 percent saturated with carbon monoxide, being apparently so limited because of the rapidity of death.

The gas in the chamber was analyzed and found to contain 16.2 percent oxygen, 4.0 percent carbon dioxide, 0.8 percent carbon monoxide. At autopsy, the outstanding findings were pharyngeal edema consistent with systemic hyperthermia. The mouth and pharynx were badly burned, leading to an obstructive edema. The trachea contained much mucus and carbon particles and the lungs were engorged with blood. The steam at 210°F caused more damage in the latter experiment than did flame at 900°F in the first experiment due

to the greater liberation of heat by the steam. In other experiments, hot air at 347°F and 563°F caused similar swelling, edema and death from asphyxiation. The mechanism in all the animals in this series was an acute obstructive edema.

Classification of Burns

Burns of the skin are said to be of either first, second or third degree intensity. In first degree burns, there is no destruction of tissue or irreversible damage. Redness (hyperemia) or accumulation of blood in the subcutaneous tissues is the most prominent sign. In second degree burns, there is complete destruction of the epidermis or superficial layers with separation from the dermis and accumulation of tissue fluid between the layers ("blistering"). In burns of the third degree, there is complete destruction of both important layers of skin (dermis and epidermis), which is not reversible. The flesh is raw and an open wound, highly susceptible to infection, is produced. If third degree burns involve more than one-third of the body surface they are generally fatal but survival from second degree burns covering more than 80 percent of the body are reported.

When skin is burned with hot water, the severity of burning depends largely on the extent of skin temperature rise and duration of the elevated skin temperature. The microscopic pathological picture may vary from no visible cell changes to complete destruction. If repeated first degree burns occur in the same site, microscopic changes may occur. The time required for healing varies directly with the time and temperature needed to injure.

In early, mild burns, the first visible change involves swelling of the cell nuclei with redistribution of the chromatin material. Further injury involves pyknosis (cell shrinkage), swelling of the cytoplasm and fragmentation of cells. The detachment of epidermis from dermis (blistering) involves changes in the basal epidermal cell layer or in the cement substance. When the temperature producing burns exceeds 131°F, coagulation of tissue fluids occurs. If the temperature change is rapid, it masks nuclear swelling and disintegration of cytoplasm. Desiccation and carbonization (charring) is the final step in the disintegration of the superficial skin layers.

When deeper (dermal) layers of skin are involved, the blood vessels constrict and then dilate immediately. If the heat rise is rapid, the blood vessels remain constricted and dilation is seen only in the deepest and best protected layers of skin. Other changes involve the accumulation of tissue fluid (edema) due to dilation of the small blood vessels and increased permeability which permits leakage of blood plasma into the tissues.

If, in a reasonably intense exposure to heat in man, blistering or vesication does not occur, it may indicate that (a) the heat was not sufficient to increase the permeability of local blood vessels or (b) there was insufficient exposure time to allow the fluid to collect, or (c) the blood flow ceased in the area possibly due to overheating, or (d) no dilation of the local blood vessels occurred, due to their insensitivity.

Even very low skin temperatures, if elevated above normal will cause burns (*e.g.*, 111°F for 6 hours) if the temperature is sustained long enough. The severity of skin burns is not an index of the severity of systemic disturbances. Deaths from elevated body temperatures may occur after long exposure to low intensity heat sources, but short exposure to high temperatures does not necessarily elevate the

body temperature. It has been shown that exposures as brief as 75 seconds to a gasoline fire were able to cause immediate death solely by overheating the skin and thereby elevating the body temperature.

The time required to produce second degree burns of equal intensity can be seen from the following table:

Time of Exposure	Temperature
1 second or less	2000-3000°F
3 seconds	700-900°F
15 seconds	212°F
20-60 seconds	160-180°F

Inhalation of air at the above temperatures produces burns of the respiratory tract with slightly longer exposure.

Tolerance of Living Tissues for Heat

Exposure of living animals to an air temperature of 752°F (400°C) for 1 minute is fatal, independent of asphyxial influences or thermal injury of the respiratory tract, either of which may lower the tolerance. Anesthetized animals are slightly less susceptible to heat since their body temperature is lower than that of conscious animals and more heat is needed to bring the internal body temperature to injurious levels.

To produce cutaneous burning, it is necessary to bring the temperature of the deeper layers of the epidermis to at least 117°F (47°C). The higher the body temperature, the lower need be the skin temperature of the superficial dermis to cause cellular death. Exposure to an ambient air temperature of about 752°F (400°C) for 90 seconds leads to a fatal hyperthermia in pigs, although 15 minutes' exposure is required at 212°F (100°C). Man requires almost twice the exposure of pigs to cause fatal hyperthermia and the sequence of events leading to death includes inhibition of respiratory centers and of the conducting mechanism of the heart, peripheral vascular collapse, with possibly an increase in plasma potassium and concurrent injury to the nervous system.

The Effect of Inhaling Heated Air

When hot air is passed into the trachea, the temperature (in the trachea) rises during inspiration and falls during exhalation. If the air is hot and dry, the temperature reaches a sharp peak and declines rapidly. If the air is moist, it reaches a peak temperature more slowly and drops much more slowly than with dry air, that is, there is a plateau effect.

There is a sharp drop in temperature between the source and the trachea, however short the distance. Moritz found that moist air at 662°F (350°C) at its source dropped to 320°-360°F (159°-182°C) inside the larynx. There was a drop from 932°F (500°C) at the source to 122°F (50°C) within the trachea under the influence of active and deep breathing.

If the air is hot enough to damage the lower air passages, it is likely to cause death by producing obstructive edema of the larynx before enough time elapses to cause marked changes deep in the respiratory tract. Thus, the lower the temperature of the air entering the respiratory tract (within certain limits) the deeper will be the site of injury. Other pathological findings seen in the respiratory tract after exposure to smoke and flame, include a deposition of carbon, reddening of the tracheal mucous membrane, and a slight accumulation of frothy edema fluid in the lungs. Hyperemia is prominent in the interalveolar septal capillaries with congestion of the smaller vessels. The local vascular damage with edema may contribute to the development of shock.

Respiratory failure occurs before the heart fails and although it may be an im-

portant contributory factor in death from flame, it is probably not the most important one. If burning of the skin is extensive, in non-fatal cases there is a loss of protection ordinarily afforded by the skin against fluid loss and infection.

In experiments in which anesthetized animals were made to inhale flame, hot air and live steam from a blast burner by inserting a tube directly into the windpipe, it was found that dry heat was rapidly dissipated in transit to the lungs. There was drop in temperature from 719°F to 181°F in the lower trachea while steam cooled only to 167°F from 212°F (or 80% drop with dry heat and 20% drop with steam). Post mortem examination showed that flame and hot air lost too much of their heat while traversing the trachea to burn the lung tissue and the lower trachea was only mildly burned if at all.

Steam, even though at a much lower temperature than hot, dry air, caused severe injury along the entire length of the trachea and in the lungs. The type of injury was a hemorrhagic edema with or without dilation of the large and small bronchi. All types of injury seemed to predispose to the development of bronchopneumonia. When hot air was not led by cannula beyond the glottis, edema developed here and death followed from obstructive asphyxiation.

The Effect of Oxygen Lack

The absorption of oxygen into the blood from the lungs is subject to the same physical laws which govern the passage of gases through semi-permeable membranes wherever found. In atmospheres in which the oxygen is reduced to 12-15 percent, muscular coordination for skilled movements is disturbed; between 10 and 14 percent, consciousness continues but judgment is faulty and muscular effort leads to rapid fatigue. Below 6 percent, breathing ceases. When only 6 to 10 percent oxygen is present, collapse occurs quickly but rapid treatment will prevent fatal outcome. Oxygen concentrations below 6 percent will cause death to occur in 6 to 8 minutes.

A significant fact related to oxygen deficient atmospheres is that before the oxygen content has become so low as to be irrespirable, it may have taken up other toxic gases which would cause injury even in the presence of an adequate oxygen supply and be more harmful than oxygen deficiency alone.

During the exertion of fire fighting, unconsciousness from oxygen lack may be instantaneous. A concentration of 4.2 percent oxygen results in a loss of coordination in 2 minutes but consciousness lasts for 7 minutes or more. Recovery is prompt if the victim is removed to fresh air and caused to breathe air containing at least 14 percent oxygen, but it must be remembered that exposure to heat increases the oxygen requirement in the same way that fever does.

Much of our knowledge of respiratory oxygen exchange in fires has been obtained from experimental work, especially on goats. This animal is suitable because the affinity of its hemoglobin for carbon monoxide is almost the same as that of man. When animals breathe 100 percent nitrogen, the oxygen saturation of arterial blood falls in 1 minute to 10 percent; regular respiration ceases in 1½ minutes and death occurs in 4 minutes.

A high body temperature of 108-111°F (42.5°-43.5°C) increases susceptibility to high carbon monoxide-low oxygen atmospheres. The oxygen depletion of the blood in fatal cases may be due to continued use of oxygen by the tissues after breathing ceases.

Causes of Deaths in Fires

Damage to the brain is probably significant in causing sudden death in fires. Patients who seem to be recovering from toxemia and with liver damage subsiding often die suddenly of respiratory failure without structural changes in the lungs. This sequence is comparable in many respects to death seen after brain injury.

Deaths occurring in persons not exposed to excess heat is probably due to oxygen deficiency and high concentration of carbon monoxide. Irritants cause great distress and pain but are secondary in causing sudden death.

In delayed deaths, that is, in individuals surviving more than 3 hours, there is a probability of sepsis, bronchopneumonia, and/or formation of pulmonary scar tissue with loss of vital function and secondary shock as a cause of death.

If the subject is severely burned, death may be due to (1) central circulatory failure (dilation by heat, capillary damage and plasma loss) because of excessive destruction of blood in superficial peripheral vessels, (2) from release of potassium from circulating cells, or (3) from loss of plasma through damaged capillaries until blood volume is greatly reduced. If the subject is not severely burned, death may be due to systemic hyperthermia leading to heart stoppage even though the temperature is not high enough to cause burning. Death (in man) from hyperthermia occurs when the body temperature reaches 108°F.

Animals exposed to flame in a series of experiments with adequate ventilation showed acute respiratory depression but blood carboxyhemoglobin of 0 to 21 percent. Five of seven animals died in 45 minutes of some form of shock, possibly due only to hyperthermia but with evidence of attendant increase in capillary permeability. Goats exposed to flame for 8 to 20 seconds usually died in 1 hour. None had sufficient carboxyhemoglobin in the blood to kill. The arterial oxygen saturation was low, although all breathed outdoor air. All animals were severely burned and each had a high serum potassium level. The blood showed hemoconcentration. In three animals, the potassium concentration was raised above lethal levels and one showed evidence of ventricular fibrillation. They stopped breathing before the heart symptoms ceased. There was no pulmonary edema; lung hemorrhages were scarce and focal. Pulmonary hyperemia was present in some animals.

Death from heat is due more particularly to the effect on the skin rather than from a general increase in body temperature. This includes (1) liberation of potassium into the blood stream so that fatal levels are reached, (2) local damage to blood vessels with edema which probably contributes to the development of shock, (3) massive stimulation of the sensory nerve endings, and (4) loss of protection normally afforded by the skin against water loss.

In practical situations, anoxia may hasten the development of ventricular fibrillation. Anoxia alone might cause it although the mechanism is uncertain. Gases and vapors may cause slowing of the heart accompanied by a fall in diastolic and systolic blood pressures. Adrenalin administered at this point might result in disordered rhythms and fibrillation.

During ventricular fibrillation, the ventricles of the heart beat very rapidly and out of rhythm with the auricles. The condition is rapidly fatal and may be caused by exposure to hydrocarbons and the simultaneous hypersecretion of adrenalin from fear or fright. When intense emotion is experienced, adrenalin is secreted by the adrenal glands and poured into the blood stream. In the presence of gasoline vapors, the effect of adrenalin is said to be synergistic, that is, the effect of the two substances is greater than the sum of the effect of the two separately.

Moritz has listed the principal causes of fire deaths as follows (but not necessarily in their order of frequency for more than one cause may operate in a single case):

1. Carbon monoxide.
2. Insufficient oxygen (anoxemia).
3. Carbon dioxide and combined effect of carbon monoxide and carbon dioxide causing prolonged hyperphea.
4. Effect of heat alone.
5. Surgical shock.
6. Bronchial and pulmonary edema with hyperemia (related to irritants, such as acid anhydrides, aldehydes and acids).
7. Other toxic gases as hydrocyanic acid, nitrogen oxides, fluorides and chlorides.
8. Ventricular fibrillation produced by inhaling vapors of hydrocarbons.

Moritz believes that heat dilates the blood vessels causing capillary damage and loss of plasma into tissue spaces, resulting in local edema. In second degree burns, there is a loss of tissue fluid which is secondary to a loss of plasma (especially a loss of plasma proteins which are needed to maintain osmotic relationships). Concentration of the blood results and red blood cells plug the small vessels. Potassium is liberated from the cells and exerts a toxic effect on muscle fibres of the heart. This toxic effect is relative, for when red blood cells are destroyed intracellular potassium is liberated and the ionic balance of the blood favors the accumulation of potassium over the normal level of extracellular sodium. This is associated with a decrease in blood volume, a fall in blood pressure and shock which, in turn, leads to destruction or inhibition of the cardioregulatory centers in the medulla, loss of vagus control of the heart and even to ventricular fibrillation, resulting in rapid, irregular and incoordinated contraction of the heart muscle. The coronary circulation may then fail. Ventricular fibrillation is essentially a disorder of excitation and conduction of the cardiac impulse. After exposure to heat during fires, ventricular fibrillation may be due to anoxemia or emotional stress as well as inhalation of hydrocarbon combustion products.

In a number of unburned experimental animals dying of strangulation, the blood potassium did not exceed 12 milliequivalents per liter. A blood temperature of 127.4°F (53°C) in capillary blood is necessary to produce toxic effects in pigs and it must be maintained for 15-20 minutes (or a skin temperature of 131°F (55°C) for 15-20 minutes). Two-thirds of the body surface must be exposed. Therefore, potassium is probably not responsible where the body is unburned as reported by Rubinstein and Persky.

In the tragic Cocoanut Grove disaster in 1942, where almost 500 lives were lost, it was apparent from the condition of the bodies that they had been exposed to flames of great intensity from burning material for a short time and for a much longer period to toxic combustion products and poisonous vapors. The exact nature of the gases and vapors was not established beyond some doubt, but it is definitely known that carbon monoxide and certain

nitrogen oxides were present. Burning about the head indicated that flames were concentrated above four feet; this finding makes it understandable that flame inhalation was frequent. The depth to which flame penetrated into the respiratory organs was difficult to determine, but characteristic tissue destruction was seen in the nostrils, larynx and trachea. Pulmonary edema in the Cocoanut Grove cases developed in a very short time. The very deep parts of the lungs were affected. Even extremely poisonous and irritant war gases do not cause pulmonary edema until some time has elapsed after exposure. A deficiency of oxygen in the blood (anoxemia) may cause pulmonary edema and when oxygen deficiency and irritant or toxic vapors are working together the time required may be shortened.

In only a few of the fatal Cocoanut Grove cases which came to autopsy was surface burning sufficiently extensive to cause death. In cases which were "dead on arrival" at various hospitals, the appearance of the body organs indicated inhalation of irritants and survival long enough to develop a serous but not a leucocytic type of reaction.

The principal cause of death was adjudged to be anoxemia, due to carbon monoxide and other gases.

Pathological Findings in the Respiratory Tract After Heat Exposure

One of the commonest forms of injury seen in fire victims is the accumulation of fluid in one or more parts of the respiratory tract, so-called edema. It is called bronchial, laryngeal, or pulmonary edema according to the location. Edema is not exclusively due to inhalation of flame, superheated air, irritant smoke or noxious gases. It has been observed in experimental animals exposed to flame and heat who had been breathing pure air through a respirator. In subjects dying immediately after exposure in a fire, edema is seldom seen and suggests that some time must elapse before the pathological process can organize. Apparently, pulmonary edema can be caused by hyperthermia alone and is also seen after exposure to carbon monoxide alone, although the latter gas is not considered to be an irritant. There is no correlation between the severity and extent of pulmonary or bronchial edema and the percent of carboxyhemoglobin in the blood.

The association of edema and exposure to excessive heat has been noted by several investigators. It may or may not terminate in death but when it does, it is due to closure of the air passages by the accumulated fluid which prevents air from reaching the lungs, actually a form of obstructive asphyxia. It may also be triggered by shock (accompanied by increased capillary permeability, not necessarily confined to the site of trauma). Psychic factors are probably of minor importance for the condition can be produced by exposing anesthetized animals to high temperatures. Pulmonary edema reduces the vital capacity of the lungs and is not dissimilar to pneumonia in this respect. In sudden death, pulmonary hemorrhage is a prominent finding at autopsy. The hemorrhage may occur very rapidly and has been seen in animals dying 1½ to 3½ minutes after exposure to heat, even those protected by respirators so that the normal carbon dioxide-oxygen relationships of the blood are maintained.

Pulmonary edema may develop rapidly following exposure to irritant gases. It may kill in a short time or the outcome may be delayed. Edema may occur with or

without occluding the air passages. If occlusion occurs, it may be due to partial plugging with cellular debris, mucus, fibrin and leucocytes from higher levels in the respiratory tree. The swelling may occlude the air passages mechanically or there may be a reflex closing of the glottis which prevents inhalation of oxygen unless the condition is relieved by surgical means. A secondary infection may occur later, either in the form of a chemically induced bronchitis or pneumonia which is usually refractory to treatment.

The essential procedure in the treatment of edema of the respiratory organs is to supply oxygen by inserting a tube in the occluded air passages. Rest is vitally important to enable the body to conserve oxygen and escape suffocation. When edema is present, it is important to guard against the development of secondary lung infection by antibiotics and supportive treatment.

The respiratory injuries seen in victims of the Cocoanut Grove disaster varied from obstructive edema of the upper air passages, in persons with severe skin burns, to delayed broncho-pulmonary damage in persons showing little or no burning of the body surface. In others, pulmonary edema was caused by the inhalation of irritants. Mallory and Brickley stated that "anoxemia plus an irritant vapor may synergistically act to produce pulmonary edema in a very short time."

Acrolein and other irritants (*e.g.*, from burning paint and oil) may cause extensive alveolar edema deep in the lungs. In the absence of irritants, edema can be caused by high carbon dioxide, high carbon monoxide and low oxygen concentrations plus an unknown factor. High carbon dioxide concentrations can cause rapid and deep respiratory damage due to stimulation of the respiratory center in which there is an effort to compensate for low oxygen concentrations.

Carbon Monoxide and Carbon Dioxide

As pointed out above, the principal cause of sudden death in fires may be a high concentration of carbon monoxide and a low oxygen concentration in the inspired air. Equilibrium between blood and air with respect to these gases is never reached in fatal cases or in short exposures, but it is probably reached in prolonged exposure to low carbon monoxide tensions. The lethality of oxygen-carbon monoxide mixtures depends on the ultimate equilibrium in the blood between hemoglobin and carboxyhemoglobin, *i.e.*, $\frac{CoHgb}{Hgb}$

The lethal degree of saturation of blood with carboxyhemoglobin lies between 60 and 80 percent. Sudden and uncomplicated deaths from carbon monoxide may occur in an atmosphere containing a high concentration of carbon dioxide. This does not happen when irritating combustion products are also present (such as aldehydes and acids), for persons are driven from the area by the irritant gases. However, in the vicinity of a slow burning coke fire, with inadequate ventilation, large volumes of carbon monoxide are produced and the death of an exposed person may be almost instantaneous.

The amount of carbon monoxide needed to produce death depends on the rate at which the gas is inhaled and the physical exertion at the time of exposure. General-

ly, the amount of carbon monoxide which will produce saturation of approximately 75 percent of the hemoglobin and transformation to carboxyhemoglobin will produce unconsciousness and usually death. This degree of saturation might be accomplished in 2 minutes during exertion in a fire.

In the Cocoanut Grove fire in 1942, three persons dying en route to the hospital showed clinical and pathological signs of carbon monoxide poisoning but the blood showed a sublethal saturation with carbon monoxide and only traces of nitrogen oxides. Postmortem examination showed pulmonary edema, petechiae and dilated bronchioles, all pointing to the inhalation of gaseous irritants.

There is a fallacy in accepting an absolute "threshold" for the toxicity of a gas. It is a misleading figure since the minimum toxic concentrations are determined usually in the presence of atmospheric air. Yet, in an actual fire, a single gas or vapor is seldom encountered and there is ample evidence to show that the sum of the toxicity potential of two or more gases or vapors is more than additive. When encountered in a fire the toxicity of such a mixture may be further increased by low oxygen concentrations and high temperatures. For example, a mixture of carbon monoxide and hydrogen sulfide in air, containing of each respectively 50 and 4 parts per 10,000 parts of air is fatal to animals when breathed, but neither gas in these concentrations is fatal when breathed alone.

Carbon dioxide, as mentioned above, causes a stimulation of the respiratory center in the brain and if breathed in excess during a fire, it inevitably causes an abnormally high intake of other gases causing toxic or lethal interalveolar concentrations which might have been avoided if carbon dioxide had been absent. In concentrations of 7-10 percent in atmospheric air, carbon dioxide may produce death if it is breathed for a relatively short time.

Carbon monoxide is dangerous only to red blooded mammals who have hemoglobin as their blood pigment. Young and healthy subjects are most quickly affected due to their active metabolism for they absorb the gas faster than do older persons with a lower metabolic activity.

To demonstrate the effect of carbon dioxide in stimulating respiration, data from a controlled experiment is of interest. Human subjects were caused to breathe mixtures of carbon dioxide varying from 4.7 to 5.2 percent carbon dioxide and 15.5 to 17.8 percent oxygen. The results may be summarized thus:

Concentration CO_2	Concentration O_2	Effect on Respiration
2.0	....	No effect.
3.5	....	Increased respiratory effort at rest.
5.2	15.8	Shortness of breath at rest; labored breathing with progressively more effort required above 4.5% CO_2.
4.3-4.7	18.2-23.4	Subjective symptoms of headache with symptoms of chill and fatigue which were less apparent when oxygen was high. Depth and rate of respiration not affected.
5.6-5.8	16.1-14.2	Subjects not conscious of effort to breathe while at rest until CO_2 reached 3.5%.

A formula has been derived from actual data by which fatal exposure to carbon monoxide can be predicted.

$T \times K_{co} = 0.15$ when T is time in hours and K_{co} is concentration of carbon monoxide, percent.

The symptoms which may be expected in one hour of exposure are:

Concentration of CO in Percent	Effect in 1 Hour Exposure
0.04	No symptoms.
.06.-.07	Headache and unpleasant symptoms.
0.1-0.12	Dangerous.
0.35	Fatal.

One part carbon monoxide in 750 parts of air, if breathed for 30 minutes is dangerous. Two deep breaths of 2 percent carbon monoxide may cause unconsciousness and death in 4 minutes.

Specific Gas and Vapor Hazards

Comparison of Carbon Monoxide and Hydrogen Sulfide

It is not well known that a lower concentration of hydrogen sulfide than of carbon monoxide will disable. Carbon monoxide is 25 times as toxic as carbon dioxide but only about one-quarter as toxic as hydrogen sulfide in equal concentrations. The following table shows a comparison of the effect of equivalent concentrations of these gases:

Percent in Air	Carbon Monoxide	Hydrogen Sulfide
0.4	Fatal in less than 1 hour	Rapidly fatal
0.1	Dangerous in 1+ hours	Rapidly fatal
0.01	Tolerable	Slight symptoms

For both of these gases, the first warning that safe limits are being exceeded is the onset of headache. This should not be disregarded, however slight, for escape soon becomes impossible. Many casualties have resulted from the belief that smoke was too thin to contain carbon monoxide or to require use of a respirator. Herein lies a fallacy for since carbon monoxide is colorless and odorless it has no characteristic which will warn of its presence.

Like carbon monoxide, hydrogen sulfide is formed when combustion is incomplete. Burning of hair, meat, hides, and wool results in hydrogen sulfide formation. It is also present in sewer gas in high concentrations. It is heavier than air and collects near the floor or ground in stagnant air spaces, such as an excavation or cellar. This is the so-called "stink damp" which so complicates fire-fighting in mines. At 0.2 percent, the sense of smell is paralyzed and increasing concentrations are not distinguishable to the nose. It is very toxic when present at .05-.07 percent by volume.

Irritant Gases

Although the lungs and associated structures are the principal sites of action for irritant fire gases, corrosive vapors such as acids and aldehyde will also affect the unprotected skin. Whatever the tissue exposed, the effect is to cause inflammation. Like inflammation of bacterial origin, it is characterized by pain, swelling, redness followed by whitening of the tissue (if the exposure is severe) and increase in the local skin temperature.

If the concentration of irritant gas is high or the exposure prolonged, fluid accumulates in the respiratory organs, being drawn from the blood and tissues and the condition is called tracheal, bronchial or pulmonary edema according to the level in the respiratory tract which is affected.

Smoke, even if composed only of finely divided carbon particles, may cause much irritation. Many smokes contain liquids in an atomized form or they may contain material which is ordinarily solid but which has been converted during the fire to a gaseous form. The visible density of smoke is not an index of its toxicity.

An example of a fire in which irritant gases figured largely was the Cleveland Clinic fire of 1931 in which 85 persons died immediately and 40 others developed fatal lung edema in 2 to 8 hours after being removed from the burning structure. In this fire, no excessive temperatures were reached and almost without exception deaths were due to inhaling nitrogen oxides from burning nitrocellulose X-ray films. The clinical course for most of these persons included a sequence of rhinitis, laryngitis, and tracheitis with copious mucus secretion. Death resulted when secretion of mucus became so extensive that maintenance of respiration was impossible. In another group, there was damage only to the small and deeper air passages and to the actual lung tissue. Associated with this were pulmonary edema, much bleeding in the deeper areas of the lungs, focal arterial and venous thrombosis and plugging of the smallest air passages by necrotic cellular debris.

The most common irritants encountered in fires are acetic acid, acetic anhydride, acrolein (from the combustion of fats, oils, petroleum products and in airplane crash fires), aldehyde, formic acid, ammonia, formaldehyde, furfural, hydrogen sulfide, pyroligneous acid, saturated and unsaturated hydrocarbons, resins, sulfur dioxide and tar. Various combinations of these are encountered in fires involving wood, paper, coal, petroleum products, textiles, animal fats and oils. Burning wool, silk, rubber, photographic film, celluloid and plastics are also notable sources of irritant gases.

While primary irritants may cause extensive and intense injury to the surface tissues of the respiratory tract, they manifest little or no systemic effect in concentrations causing death. However, the secondary irritants, or those acting after absorption, do cause generalized or non-localized injury. If the injury is confined to the respiratory tract, it is generally noted that the deeper the site involved, the poorer is the prognosis but the less painful is the condition. Thus, edema of the trachea or pharynx at the upper end of the tract is accompanied by great pain but the condition clears up fairly quickly whereas pulmonary edema is accompanied by less pain but is much more serious and more commonly fatal. In severe pulmonary edema, so great is the accumulation of fluid in the lungs that the patient literally drowns in his own body fluids. Essentially, this is what happens in the final stage of fatal pneumonia.

In fires involving refineries and storage areas for petroleum products, the chief irritant is acrolein. This has been so named because of the acrid, sharp and irritating character of the vapor. It is the chief irritant in the exhaust from internal combustion engines and is often mistakenly assumed by mechanics to be carbon monoxide. When it is absent, they often take very great risks. Unburned gasoline vapors can be as toxic and they are often found

floating on water surfaces where they constitute both a toxic and fire hazard. Sewer gases may be combustible, explosive and toxic. They contain deadly hydrogen sulfide and sulfur dioxide, together with other gaseous products of putrefying and fermenting material. In waterfront and marine fires, chlorine is produced when sea water acts on batteries exactly as occurs in submarine disasters and salvage activities. Many of these gases are so highly irritant and act so promptly that an unprotected man will seek to escape from them before the concentration becomes lethal. However, an unprotected man, rendered unconscious or helpless for other reasons may succumb to them.

Chlorine is released by the electrolysis of sea water, by the leakage of chlorine cylinders and by leakage of acid into bleaching powder or hypochlorites. It is corrosive to the body surface or lungs in concentrations of .004-.006% and can cause dangerous illness in ½ to 1 hour.

Fires in chemical plants present as many fire gas problems as there are compounds involved. It must be assumed in such locations that dangerous gases are present and the wearing of respirators never omitted. Textile fires in mills, weaving sheds or warehouses, especially those containing silk and wool, may produce hydrocyanic acid and other dangerous gases. In pure form, hydrogen cyanide may warn by its odor which resembles almonds, but in fires this odor is usually obscured by stronger odors. Collapse and death may be caused by hydrogen cyanide without any warning.

A few gases deserve comment because of their marked toxicity. In subtoxic concentrations, they are considered unpleasant but their lethal qualities are too little appreciated.

Sulfur Dioxide

Although lethal concentrations of this gas are not respirable because of the intense irritation it causes, damage to unprotected or unconscious or helpless individuals may be serious. The concentration of sulfur dioxide detectable by odor is 3-5 p.p.m. Irritation of the throat is caused by 8-12 p.p.m. while 20 p.p.m. causes coughing and eye irritation. Above this concentration, irreversible injury results after exposure of one hour.

Nitrogen Oxides

Nitrogen oxides are much more toxic than is commonly realized, since in the water vapor of the lungs they form nitrous or nitric acids. The fumes from nitric acid are usually nitrogen tetroxide but it is often mixed with nitrous oxide and nitrogen dioxide. Damage from this group may often be sustained without marked discomfort at the time of exposure. In practice, the chief sources are nitrocellulose containing materials, from the decomposition of smokeless powder, celluloid film and pyroxylin plastic materials.

Nitrogen dioxide is quite as toxic as hydrogen sulfide and there is a smaller safety margin between the minimum toxic and the minimum lethal dose. The slower action may result in edema of the respiratory organs in 3-8 hours.

10-40 p.p.m. is the maximum concentration of nitrogen dioxide tolerable for prolonged exposure.

62 p.p.m. is the minimum which causes throat irritation.

100-150 p.p.m. causes coughing and is dangerous for exposures of one hour.

200-700 p.p.m. is rapidly fatal after a short exposure.

Men exposed to this fire gas should be kept in bed several days after even minimal exposure to limit the lung injury (which is often delayed in appearance) as much as possible. Nitrogen oxides tend to anaesthetize the throat so that no initial discomfort is experienced.

Cyanides

Hydrogen cyanide is formed by the action of water and acids on cyanides. When cyanides are known to be present in a burning building, protection should be assured by wearing of waterproof suits, gloves and a respiratory device furnished with a special cyanide canister. The odor warns of its presence but it may be obscured by other odors or the olfactory sense may be quickly paralyzed and unable to perceive increasing concentrations, especially if the exposed person is suffering from an upper respiratory condition such as chronic sinusitis.

Exposure to 20 p.p.m. produces slight symptoms in several hours and exposure to 100 p.p.m. or 0.01 percent is very dangerous for even a short time. Exposure to 2,000 p.p.m. is invariably fatal even with prompt treatment. When ordinary cyanides are ingested by mouth, 200 milligrams is the fatal dose. Absorption can take place through the skin, especially if an abrasion or other break in the continuity of the skin is present.

Refrigerants

Refrigerants are usually toxic at low concentrations, but under conditions of normal use are not dangerous. Many are fat soluble and so are effective in conformity to the Meyer-Overton law of drug action which postulates that substances are harmful in proportion to their solubility in fatty materials. This is intimately related to the ease with which they pass through cellular membranes. Refrigerants which are harmless may be decomposed to toxic substances by heat or flame, and since refrigerating systems are so frequently damaged in fires they require consideration as fire gases.

Underwriters' Laboratories carried out an extensive study in 1933 in which they examined the toxicity of various refrigerants at room temperatures and in the presence of flame and hot wires. They were able to classify refrigerants in six classes on a time-concentration basis. In order of their decreasing toxicity, the refrigerants run about as follows: sulfur dioxide, ammonia, methyl bromide, methyl formate, carbon tetrachloride, dichloroethylene, methyl chloride, ethyl bromide, methylene chloride, ethyl chloride, monofluorotrichloromethane, carbon dioxide, butane, ethane, propane, dichlorodifluoromethane and dichlorotetrafluoroethane.

While all of these are toxic and even lethal if the exposure be long enough and the concentration high enough, a few of them deserve comment because of special properties. Ammonia, although it gives ample warning, will cause irreversible blindness if the exposure to 0.5 percent be continued for 30 minutes. Dry ammonia will not affect the skin, although in solution, burns which are particularly refractive to healing are caused. Ammonia vapor is combustible in air in concentrations of 16-23 percent.

Butane, ethane and propane were found in the study cited not to be dangerous at 5 percent concentration for 2-hour exposures, but higher concentrations cause drowsiness, anaesthesia and muscular weakness.

Both ethyl bromide and ethyl chloride are anaesthetics and may decompose to the

basic elementary gases or to the acid form of the halogen. They give slight warning by odor, but a person may tolerate a harmful dose until helpless.

Methyl bromide and methyl chloride act similarly to the ethyl homologues and the former disappears so rapidly from the body that no trace may be found at autopsy in a fatal case caused by it. Both cause permanent damage to the nervous system in non-fatal cases.

Carbon Disulfide

Carbon disulfide fumes harrass, blind and irritate the nose, throat and air passages with coughing and eventual choking due to laryngeal edema. Fumes containing carbon disulfide may cause clouding and denuding of the cornea, leading to diffuse corneal opacity with possible edema, difficulty in breathing with eventual laryngeal edema, pulmonary congestion and almost complete occlusion of the glottis. Deposits of carbon may be seen in the bronchial tree and the lung is congested and edematous.

Carbon disulfide is toxic in concentrations of .05 percent and the vapor becomes explosive when the concentration reaches 1.2 percent. When present to the extent of 3200 to 3500 parts per million, serious illness may be caused if breathed for ½ to 1 hour. Direct skin contact with this compound should be avoided. It yields sulfur dioxide when burned, which in a volume of .02 percent may cause serious illness in 30 minutes. Carbon disulfide may also yield carbon monoxide.

The appearance of petechiae or tiny skin hemorrhages resembling minute bruises is often seen but is non-specific and does not necesarily indicate exposure to any given agent or gas. Petechiae may be present in anoxia from any cause and may accompany pulmonary edema. Nitrogen oxides or several other gases may cause them. They result from subcutaneous hemorrhage and may be caused by anoxia alone, which also alters capillary permeability resulting in leakage of plasma from blood vessels into the surrounding tissues. Petechiae do not necessarily indicate the presence of phosgene.

Miscellaneous Gases

Two gases deserve mention because of their high toxicity, although they are infrequently encountered in fires. Arsine ($As H_3$) is sometimes produced from the combustion of arsenical insecticides or from arsenical ores. 0.001 percent or 1 part in 100,000 is fatal after exposure of 8 hours, and 0.005 percent or 1 part in 20,000 after an exposure of one hour. The onset of symptoms may be delayed only to be followed by a painful death in 2-5 days. Phosgene or carbonyl chloride ($COCl_2$) is dangerous in 30-60 minutes after exposure to 25 p.p.m. and lethal after a few minutes' exposure to 250 p.p.m. It is probable that this gas is formed from the breakdown of some of the chlorinated hydrocarbons.

Carbon tetrachloride, used as a solvent and in small quantities as an extinguishing agent, is an anaesthetic which is lethal above 2.5 percent after 1½ hours.

Acetic acid vapor is formed by distillation in fires involving wood. (This is essentially the process by which vinegar is produced synthetically.) The corrosive acids can produce skin burns and are dangerous, for even though they do not burn, they may vaporize and give off vapors which damage the lungs when inhaled. These include acetic, hydrochloric, formic, hydrofluoric, hydrofluosilic, nitric, and sulfuric acids. Peroxides act similarly and are very irritant to skin, eyes and lungs. They are dangerous also because they are explo-

sive as well as strongly caustic. Bromine compounds give off a poisonous and caustic vapor when heated, and if this is inhaled, low concentrations may cause irreparable lung damage. Picric acid is generally classed with high explosives and should be so regarded. Phosphorus compounds give off phosphorus oxides and may form dangerous phosphorus pentasulfide. Phosphorus burns to yield toxic fumes.

Chemical Action and Structure

The specialized field of molecular configuration and its relation to pharmacological action is one which has just begun to come into its own. Pharmacologists are beginning to utilize such knowledge to tailor new drugs to order. However, some facts have been known for a long time in relation to toxicity, and a few generalizations are pertinent in relation to fire gases. For example, it has been substantiated that in a homologous series of hydrocarbons, the greater the number of carbon atoms the greater is the toxicity. Thus, propane and butane can be expected to be more toxic than methane. Conversely, as the number of hydroxyl or OH groups increases, the toxic action decreases. The substitution of a carboxyl group for a hydrogen atom prevents anaesthetic action and replacing the hydrogen of a carboxyl group restores the anaesthetic action to a certain extent. The substitution of a halogen for a hydrogen atom increases the anaesthetic action and also decreases the effect of a group of compounds of a homologous series on the nervous system.

Emergency Treatment

First aid treatment is often carried out by lay persons near the scene of a fire and the methods employed are often potentially harmful. The best measure for treating persons rendered unconscious by gases is by displacement from the lungs and administration of oxygen. In principle, the prime factor of treatment of gas poisoning is elimination by the same route as that by which entry was effected. Gas casualties require specialized treatment and the need to call a physician promptly is obvious. Speed is of the greatest importance, and when the physician is called he should be told what condition he will be expected to treat. First aid should be started at once and should embody the following steps:

1. The victim should be removed to fresh air.

2. The victim should make as little exertion as possible and should be carried on a stretcher if possible. This is to keep his oxygen requirement to the minimum and to inhibit further absorption of toxic gas which may be in the lungs but unabsorbed by the blood stream. Any additional exertion requires the use of more oxygen and aggravates the condition.

3. The victim should be kept quiet and warm.

4. If he is breathing normally, no artificial respiration should be given. Since a gassed person lives only 5-10 minutes after breathing stops, artificial respiration should be given promptly if needed. If available, oxygen should be administered in carbon monoxide poisoning without waiting for the arrival of a physician.

5. No liquid stimulants should be given to an unconscious person. There is grave danger that they will go into the trachea rather than the esophagus and add to respiratory difficulties already present or even drown the victim.

Artificial respiration should be continued for a long time. Recovery from oxygen deficiency is more prompt than when toxic gases are involved. It is trite but very important to remark that the time to learn artificial respiration is before one needs to use it.

Artificial respiration should be begun promptly and continued until consciousness is regained or until death is pronounced by a physician.

The administration of brandy or other spirits is very unwise and may add to the physiological depression of the injured person. Dousing in cold water may cause shock, as will attempts to "walk" a gas victim, or vigorous slapping of his feet. Rest and quiet are essential, and a man who has been unconscious should never be allowed to return to his post until he has had a period of rest. In eliminating carbon monoxide from the blood, there should be no interruption in treatment and artificial respiration should be continued for at least 4 hours. The patient should not be moved once he is removed from danger.

The table below shows the approximate time during which air or oxygen need be administered to eliminate 50 percent carboxyhemoglobin from blood.

By breathing	air	140	minutes
" "	oxygen	85	"
" "	air plus 5% CO_2	80	"
" "	oxygen plus 5% CO_2	20	"

Appendix

In the text, reference has been made to the anatomical structure of the skin and respiratory tract. A brief summary is included for orientative purposes.

The Structure of Skin

The skin consists of two main layers, the outer of which is called the *epidermis* and the inner called the *dermis*. Beneath these lies the *subcutaneous* tissue, a loose connective tissue containing deposits of fat. Properly, this latter is not a part of the skin but is intimately connected with it in structure and function.

The outer part of skin (epidermis) consists of a basal layer where new growth takes place by cell division (mitosis) and an outer layer which is not very active functionally. When new cells are formed in the basal layer they push up to the surface of the skin, undergoing chemical changes while this is happening. The cell nucleus also changes and degenerates. When the cells reach the surface, the nucleus has usually disappeared and the cells are thickly packed and toughened. The nutrition of this layer comes by way of blood and lymph vessels from the lower

skin layer (dermis). There are nerve fibers in all layers of skin.

The dermis is dense and can also be subdivided into two layers, the upper known as the *cutis* or papillary layer and the deeper or *reticular* layer. The sweat glands and the hair shafts lie in the dermis although they originate in the basal layer of the epidermis and push down into the dermis. The small blood vessels which bring nutriment to the skin extend to the point where the two layers of skin join (the dermal-epidermal interface), then reverse their direction and rejoin the underlying network of blood vessels.

The Structure of Respiratory Tract

The mouth and nose lead to a hollow structure behind the soft palate which is called the *pharynx* and here the respiratory and digestive tracts divide into separate tubes. The tube which leads to the lungs is called the *trachea.* Below the pharynx is the larynx, and in this organ are found the vocal cords, important to speech. The opening to the *larynx* can be partially closed by a lid of cartilage called the *epiglottis.* The area beneath the epiglottis and within the larynx is known as the *glottis.*

The *trachea* is the long tube running down from the larynx in front of the esophagus (*i.e.,* at the front of the neck). It divides at its lower end into two short tubes called the *bronchi,* which enter the lungs in their mid-portion at the mid-line of the chest. The bronchi divide and subdivide into shorter tubes called bronchioles which are within the lungs. The bronchioles ultimately divide into *alveolar ducts* from which lead air sacs or *alveoli,* which are the most important functional structures in the lungs. It is here that oxygen and carbon dioxide exchange between blood and air takes place.

All the structures of the respiratory system are lined by a structure resembling the skin in many respects (respiratory epithelium), which secretes mucus.

The following tables are included to show the approximate concentrations of gases causing comparable effects in given unit time. It should be remembered, in using these tables, that the effect of a given concentration may be modified by a number of factors discussed in the text.

Acute Physiological Response to Gases and Vapors in Air

Substance	1 Kills most animals in short time		2 Dangerous to life in 30-60 min.		3 Max. conc. tolerated for 60 min. without serious disturbance		4 Slight symptoms after several hours or max. conc. for prolonged exposure (8 hrs.)	
	mg./l.	ppm.	mg./l.	ppm.	mg./l.	ppm.	mg./l.	ppm.
Acrolein	4.1	1,750	0.35-0.55	153-240				
Ammonia	3.5-7.0	5,000-10,000	1.75-4.5	2,500-6,500	0.2-0.35	300-500	0.6-0.7	85-100
Arsine	0.75-1.0	250-300	0.05-0.2	15.5-60	0.02-0.06	6.3-20	0.01	3.1
Carbon dioxide	90-540	50,000-300,000	60-144	33,000-80,000	60-108	33,000-60,000	20-48	11,000-30,000
Carbon disulfide	6-15	2,000-4,800	3-12	1,000-3,850	1.5-5	480-1,600	1.0-1.2	300-390
Carbon monoxide	2-4.6	1,800-4,000	1.7-2.3	1,500-2,000	0.5-1.0	450-900	0.12-0.2	100-200
Carbon tetrachloride	350-560	50,000-80,000	150-200	24,000-32,000	60-80	4,000-13,000	10	1600
Chlorine	2.5-3.2	900-1,000	0.1-0.2	35-60	0.1	3.5-4.0	0.001-0.003	0.35-1
Ethyl bromide	446-892	100,000-200,000	44.6-89.2	10,000-20,000	26.8	6,000	7.6-13.4	1,700-3,000
Ethyl chloride	396-792	150,000-300,000	158-264	60,000-100,000	106	40,000	52.0	20,000
Hydrogen chloride	1.5-4.5	1,000-3,000	1.5-3.0	1,000-2,000	0.06-0.15	40-100	0.01-0.07	7-50
Hydrogen cyanide	0.2-0.5	200-480	0.1-0.2	100-240	0.05-0.06	50-60	0.02-0.04	20-40
Hydrogen fluoride	1.5	1,800	0.05-1.0	50-1,200	0.01-0.1	10-120	0.002-0.024	3-30
Hydrogen sulfide	0.8-4.2	600-3,000	0.6-0.9	400-700	0.24-0.45	170-300	0.1-0.2	70-150
Methyl bromide	77.8-155.6	20,000-40,000	7.9-15.6	2,000-4,000	3.9	1,000	0.19-0.66	50-170
Methyl chloride	310-620	150,000-300,000	41.3-82.6	20,000-40,000	14.5	7,000	1.0-2.1	500-1,000
Nitrogen oxides	0.5-1.4	240-700	0.2-0.3	100-150	0.1-0.2	50-100	0.06-0.08	30-40
Phosgene	0.2-2.0	50-500	0.1	25			0.004	1
Phosphine	1.4-2.8	1,000-2,000	0.56-0.84	400-600	0.14-0.26	100-190	0.1	7
Sulfur dioxide	1.0-7.8	400-3,000	0.39-1.3	150-500	0.13-0.64	50-245	0.02-0.26	8-100

Conversion from ppm. to mg./l. and vice versa are approximate.

From the Analytical Chemistry of Industrial Poisons, Hazards and Solvents, by Morris B. Jacobs, Ph.D., Interscience Publishers, Inc., 1941.

Probable Safe Concentration Limits of Exposure for Gases

Substance	[1] Cal.		[2] Conn.		[3] Dalla Valle		[4] Matt		[5] Mass.		[6] Soviet Union		[8] Sayers	
	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm
Ammonia	0.076	100			0.064	85	0.07-0.14	100-200	0.076	100	0.029	40	...	...
Arsine	0.003	1	...	...	0.01	3.1	...	...	0.003	1	0.003	1	...	...
Bromine	...	...	...	...	0.001-0.002	0.15-0.3	0.001-0.002	0.15-0.3	...	...	...	...	0.007	0.1
													[7]	
Carbon dioxide	10.0	5500	...	...	10.0	5550	...	...	...	...	...	...	Wis.	
Carbon monoxide	0.12	100	0.12	100	0.12	100	...	...	0.12	100	0.008-0.016	8-16	0.12	100
Chlorine	0.003	1	0.003	1	0.001	0.35	0.003-0.006	1-2	0.003	1	0.001-0.002	0.35-0.6	...	...
Hydrogen chloride	0.015	10	0.015	10	0.015	10	0.015	10	0.015	10	...	...	...	...
Hydrogen cyanide	0.02	20	0.02	20	0.02	18	...	...	0.02	20	...	...	...	...
Hydrogen fluoride	0.0027	3	0.0027	3	0.0027	3	...	...	0.0027	3	...	...	...	...
Hydrogen sulfide	0.03	20	0.075	50	0.05	35	...	...	0.03	20	0.003-0.015	2-10	...	...
Nitrous fumes NO_2	0.027	10	0.108	40	0.108	39	...	...	0.027	10	...	...	0.108	40
Phosphine	...	...	...	...	...	...	...	...	0.003	2	...	...	...	...
Sulfur dioxide	0.03	10	0.03	10	0.03	10	...	...	0.03	10	0.01-0.04	3-13	...	...

Conversions from ppm. to mg./l. and vice versa approximate.

From the Analytical Chemistry of Industrial Poisons, Hazards and Solvents, by Morris B. Jacobs, Ph.D., Interscience Publishers, Inc., 1941.

Probable Safe Concentration Limits of Exposure for Vapors of Several Investigators

Substance	1 Cal.		2 Conn.		3 Della Valle		4 Flury		5 Mass.		6 Soviet Union		7 Wis.	
	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm	mg/l	ppm
Benzene	0.34	100	0.34	100	0.34	100	0.1	31.3	0.25	75	0.05-0.17	15-55	0.34	100
Carbon disulfide	0.003	1	...	...	0.25	85	0.01	3.2	0.05	15	0.01	3.2	0.003	1
Carbon tetrachloride	0.69	100	0.69	100	0.69	100	0.2	31.7	0.69	100	...	...	...	...
Chloroform	0.53	100	...	...	...	...	0.2	40.2	...	...	...	...	...	...
Ethyl chloride	57.6	20,000	...	...	28.8	10,000	...	...	...	...	...	...	...	...
Methyl bromide	...	...	...	...	0.05	100	...	...	...	...	...	...	...	...
Methyl chloride	1.1	500	...	...	2.6	1200	0.5	242	...	...	...	...	...	...
Phosgene	0.0044	1	0.0044	1	0.0044	1	0.001	0.25	...	...	...	...	...	...

Conversion from ppm. to mg./i. and vice versa are approximate.

Condensed from the Analytical Chemistry of Industrial Poisons, Hazards and Solvents, by Morris B. Jacobs, Ph.D., Interscience Publishers, Inc., 1941.

1) ...
2) ...
3) ...
4) ...
5) ...
6) ...
7) ...
8) ...
9) ...
10) ...
11) ...
12) ...
13) ...

References for Fire Gas Report

1) Hamilton, A., "Industrial." Ch. V. Harper and Brothers, N. Y., 1934.

2) Henderson, Y. and Haggard, H. W., "Noxious Gases," 1943. The Chemical Catalog Company, N. Y., 1927.

3) Mendelssohn, K. and Rossiter, R. J., Quart. J. exp. Physiol., 32, 301, 1944.

4) Jacobs, M. B., "Analytical Chemistry of Industrial Poisons, Hazards and Solvents." Interscience Publishers, Inc., N. Y., 1941.

5) McNally, W. D., "Medical Jurisprudence." W. B. Saunders, Philadelphia, 1939.

6) Sayers, R. R., U. S. Bureau of Mines Technical Paper No. 334, 1923.

7) Gonzales, T., et al, Legal Medicine and Toxicology, N. Y., 1937.

8) Sagers, R. R. and Yant, W. P., U. S. Bureau of Mines, Technical Papers No. 373, 1925.

9) Olsen, J. C., Brunjes, A. C. and Sabetta, Victor J., "Gases Produced by Decomposition of Nitrocellulose Photographic Films." Ind. and Eng. Chemistry, 22, 860, 1930.

10) Ferguson, George E., "Fire Gases," National Fire Protection Association Quarterly, October 1933.

11) Fieldner, A. C., Katz, Sidney H. and Kinney, S. P., "Gas Masks for Gases Met in Fighting Fires." U. S. Bureau of Mines, Technical Paper No. 248, 1921.

12) Cameron, A. M., "Chemistry in Relation to Fire Risk and Fire Extinction." Sir Isaac Pitman and Sons, Ltd., 1944.

13) Olsen, J. C., Ferguson, G. E. and Scheflon, L., "Gases from Thermal Decomposition of Common Combustible Materials." Ind. and Eng. Chem., 25, 599, 1933.

14) Easton, W. H., "Smoke and Fire Gases," Ind. Medicine, Oct. 1942.

15) Easton, W. H., "Irritating Vapors Produced by Burning Cellulose Materials." J. Ind. Hyg. and Tox., 27, 211, 1945.

16) Rogers, A., "Manual of Industrial Chemistry." 3rd ed. Sugar Publishing Co., 1920.

17) Sayers, R. R., et al, U. S. Public Health Bulletin No. 185, 1929.

18) McLean, R., Moritz, H. and Roos, A., Studies of Thermal Injury, VI. J. Clin. Invest., 26, 497, 1947.

19) Roos, A., Weisiger, J. R. and Moritz, A., Studies of Thermal Injury, VII. J. Clin. Invest., 26, 505, 1947.

20) Mallory, T. B. and Brickley, W. J., "Management of Cocoanut Grove Burns at Massachusetts General Hospital." Ann. Surg., 117, 865, 1943.

21) Kahn, R. H., "Uber die Entwörmung des Carotidenblutes." Arch. f. anat. u. Physiol. Leipzig Suppl. Bd., 81, 1904.

22) Scudder, J., Smith, M. E. and Drew, C. R., "Plasma Potassium Concentration of Cardiac Blood at Death." Am. J. Physiol., 126, 337, 1939.

23) Ham, T. H., "Studies on Destruction of Red Blood Cells." Arch. Int. Med., 64, 1271, 1939.

24) Henriques, F. C. and Moritz, A., Studies of Thermal Injury, I. Am. J. Path., 23, 531, 1947.

25) Goodman, L. and Gilman, A., "Pharmacological Basis of Therapeutics." The MacMillan Company, N. Y., 1941.

26) Boyd, W., "Textbook of Pathology." Lea and Febiger, Philadelphia, 1940.

27) Bard, P. (editor), "Physiology in Modern Medicine." C. V. Mosby Co., St. Louis, 1938.

28) "Handbook of Chemistry and Physics." Chemical Rubber Publishing Co., 22nd edition, 1937-1938.

29) Patty, F. A. (editor), "Industrial Hygiene and Toxicology." Interscience Publishers, Inc., N. Y., 1948. Vols. I and II.

30) Little, Arthur D., Inc., "Safety Manual for Ship Salvage Operations." Prepared for Bureau of Ships, U. S. Navy, 1942.

31) N.F.P.A., "Handbook of Fire Protection," 10th edition, 1948.

32) Loewy, L., "Die chronische Kohlenoxydvergiftung." Zentralbl. f. Gewerbehyg., 3, 153, 1926.

33) Doremus, C. A. and McNally, W. D., "Gaseous Poisons." In Legal Medicine, 1923, Vol. 2, p. 431.

34) Drinker, C. K. and Cannon, W. B., "Carbon Monoxide Asphyxia." The Problem of Resuscitation. J. Indust. Hyg., 4, 463, 1922-23.

35) Claude, H., "On Nature of Nerve Injuries Caused by Carbon Monoxide Poisoning." Tr. Internat. Cong. Med., 1913. London, 1914, Sec. 11, Part 2, p. 343.

36) Delafield, F. and Prudden, T. M., "Textbook of Pathology," 12th ed., 1920, p. 480.

37) Abt, I. A. and Witt, D. B., "A Case of Carbon Monoxide Poisoning in a Child." M. Clin. No. Amer., 5, 1645, 1921-22.

38) Lewin, L., "Die Kohlenoxydvergiftung." Berlin, 1920.

39) Grinker, R. R., "Parkinsonism following Carbon Monoxide Poisoning." J. Nerv. and Ment. Dix., 64, 18, 1926.

40) Henderson, Y., "Carbon Monoxide Poisoning." J.A.M.A., 67, 580, 1916.

41) Henderson, Y. and Haggard, H. W., "Health Hazard from Automobile Exhaust Gas in City Streets, Garages and Repair Shops." J.A.M.A., 81, 385, 1923.

Index to Advertisers

	Page
Acme Fire Alarm Company, Inc.	A2
American District Telegraph Company	A1
Ansul Chemical Company	A7
"Automatic" Sprinkler Corporation of America	A34
Blaw-Knox Company	A11
Cardox Corporation	*Inside Front Cover*
Central Automatic Sprinkler Company	A26
Central Station Signals, Inc.	A14
Certain-Teed Products Corporation	A3
Chicago Bridge & Iron Company	A21
C-O-TWO Fire Equipment Company	A12
Fenwal, Incorporated	A9
Gamewell Company	*Inside Back Cover*
Globe Automatic Sprinkler Company	A24
Grinnell Company	*Back Cover*
Gustin-Bacon Manufacturing Company	A30
Wm. E. Hooper and Sons	A4
Walter Kidde & Company	A8
Kinnear Manufacturing Company	A10
M & H Valve & Fittings Company	A32
R. C. Mahon Company	A15
Mosler Safe Company	A5
National Fire Protection Association	A23
National Foam System, Inc.	A31
Owens-Corning Fiberglas Corporation	A20
Pittsburgh-DesMoines Steel Company	A16
Randolph Laboratories, Inc.	A25
Reliable Automatic Sprinkler Company	A19
Rockwood Sprinkler Company	A17
Safe Manufacturers National Association	A28
Shand and Jurs Company	A33
Star Sprinkler Corporation	A22
Tokheim Oil Tank and Pump Company	A18
U. S. Plywood Corporation	A13
Vapor Recovery Systems Company	A6
Viking Corporation	A29
Vonnegut Hardware Company, Von Duprin Division	A27

The new Ford Parts Depot at Cincinnati, Ohio, has just been completed under a country-wide expansion program described as "part and parcel of Ford's 'Look Ahead' policy to better serve Ford owners."

A criterion of practicability and efficiency, the Cincinnati Depot employs a combination of ADT Central Station Services to provide complete AUTOMATIC protection against fire, burglary and other hazards. These include: ADT Sprinkler Supervisory and Waterflow Alarm and ADT Burglar Alarm Services.

ADT Automatic Protection provides the highest degree of security at the lowest cost. Thousands of progressive business establishments from coast to coast are similarly protected. Descriptive booklets upon request.

ADT

Controlled Companies of
AMERICAN DISTRICT TELEGRAPH COMPANY
155 Sixth Avenue, New York 13, N. Y.
CENTRAL STATIONS IN PRINCIPAL CITIES

We engineer, design and manufacture:

Interior Fire Alarm Signaling Systems.

Automatic Heat Actuated Fire Alarm Signaling Systems.

Standpipe Fire Line Control and Signaling Systems.

Central Office Systems for Manual Fire, Automatic Heat Actuated Fire Alarm Systems, Sprinkler Alarm and Supervision, Watch Patrol Recording and Kindred Systems.

Supervisory Systems for Detecting Excessive Heat, Pressure and Low Voltage in Transformer Sub-stations and to Automatically Disconnect the Sub-stations from the Line and Load Sides of the Systems.

Local Sprinkler Alarm and Supervisory Systems.

Smoke and Heat Detecting Systems for Air Conditioning Systems.

Sprinkler Waterflow Detectors.

120 Volt A.C. Vibrating Bells.

Emergency Switches to Shut Down Fuel Oil Systems, Ammonia Compressors and Air Conditioning Systems.

Ground Detector Systems for Hospital Operating Rooms.

ACME FIRE ALARM CO., Inc.

106 SEVENTH AVE., NEW YORK CITY, N. Y.

Chicago accepts FIRESTOP BESTWALL®

● Phenomenal! The one word that describes the meteoric acceptance by local building codes of CERTAIN-TEED's amazing new FIRESTOP BESTWALL.

● FIRESTOP BESTWALL—the *only* gypsum wallboard with single-layer fire resistance of 1 hour for both walls and ceilings—also has received enthusiastic FHA Specification acceptance.

● Revolutionary FIRESTOP BESTWALL—offering up to three times the fire resistance of ordinary gypsum wallboard—is the *only* firestop board listed under the Re-Examination Service of Underwriters Laboratories. Inc. and so labeled.

And this greater fire protection costs less and requires minimum application time.

Write today for a folder giving complete information on FIRESTOP BESTWALL—the remarkable CERTAIN-TEED development.

FIRESTOP BESTWALL

now has building code acceptance by many cities including:

Atlanta, Ga.	Miami, Fla.
Baltimore, Md.	Milwaukee, Wisc.
Birmingham, Ala.	Nashville, Tenn.
Cleveland, Ohio	New Orleans, La.
Denver, Colo.	Rochester, N.Y.
Detroit, Mich.	St. Louis, Mo.
Fort Worth, Tex.	Spokane, Wash.
Kansas City, Mo.	San Francisco, Calif.
Los Angeles, Calif.	

And other areas, besides commissions and councils.

Asphalt Roofing • Shingles • Sidings
Asbestos Cement Roofing and Siding
Shingles • Gypsum Plaster • Lath
Wallboard • Roof Decks
Acoustical Tile Insulation Fiberboard

BLOCK THAT FIRE HAZARD WITH

The revolutionary Hooperwood FIRE-CHIEF® process really makes canvas highly fire-resistant. FIRE-CHIEF also makes the canvas resistant to the ravages of water, weather, and mildew. Tensile strength is preserved, and the canvas stays pliable. It lasts *several times* as long as untreated canvas.

FIRE-CHIEF is available in three forms: As finished Hooperwood FIRE-CHIEF Canvas; as protection we apply to the customer's own fabrics; as FIRE-CHIEF Compound to be applied to new or used canvas. Write us today for further information on Hooperwood FIRE-CHIEF Canvas and FIRE-CHIEF processing.

WM. E. HOOPER & SONS CO.

General Sales Offices: **Juniper and Cherry Sts., Philadelphia 7, Pa.**
320 Broadway, New York 7 • 300 W. Adams St., Chicago 6
Hooperwood Mills: **Woodberry, Baltimore 11, Md.**

Which of these 4 dangerous ideas do you have?

(Any *one* of them could put you out of business)

1. DO YOU HAVE THE IDEA your *accounts receivable* and other business records will *always* be there when they're needed? Don't be *too* sure. Many a businessman has discovered, *after a fire,* that the records he thought safe, were ashes . . . and the business that depended on them, totally ruined.

2. DO YOU HAVE THE IDEA an old, *heavy-walled safe* will guard *your* records from fire? It's a dangerous idea. Old safes without an Underwriters' Laboratories, Inc. "A" Label often act as *incinerators* when the temperature gets above 350° F. They *cremate* records.

3. DO YOU HAVE THE IDEA a *fireproof building* is a sure-fire protection? Just ask a fireman. You'll find that buildings like this only *wall-in* an office fire. They actually make it *hotter!*

4. DO YOU HAVE THE IDEA your *fire insurance* would cover all your losses? Take a good look at your policies or ask your insurance broker or C.P.A. You'll find you have to prepare a proof-of-loss statement before you can collect fully. Could *you* do it—without inventory records?

Don't gamble your whole business future.
Get a modern Mosler "A" Label Record Safe.

Better face this fact squarely: 43 out of 100 businesses that lose their records by fire never reopen. Don't risk it. Decide, right now, that *your* business records are going to have *real* protection—the world's finest. That means the protection of a modern Mosler "A" Label Record Safe that has passed the Independent Underwriters' Laboratories, Inc. severest test for fire, impact and explosion. Consult your nearest Mosler dealer, he will tell you how little it costs to give your records and your business the protection they need.

Consult classified telephone directory for name of the Mosler dealer in your city, or mail coupon now for informative, free booklet.

The **Mosler Safe** *Company*
Since 1848
HAMILTON, OHIO

World's largest builders of safes and vaults . . . Mosler built the U.S. Gold Storage Vaults at Fort Knox and the famous bank vaults that withstood the Atomic Bomb at Hiroshima

The Mosler Safe Company • Department NF-1 Hamilton, Ohio.
Please send me free booklet giving the latest authentic information on how to protect the vital records on which my business depends.

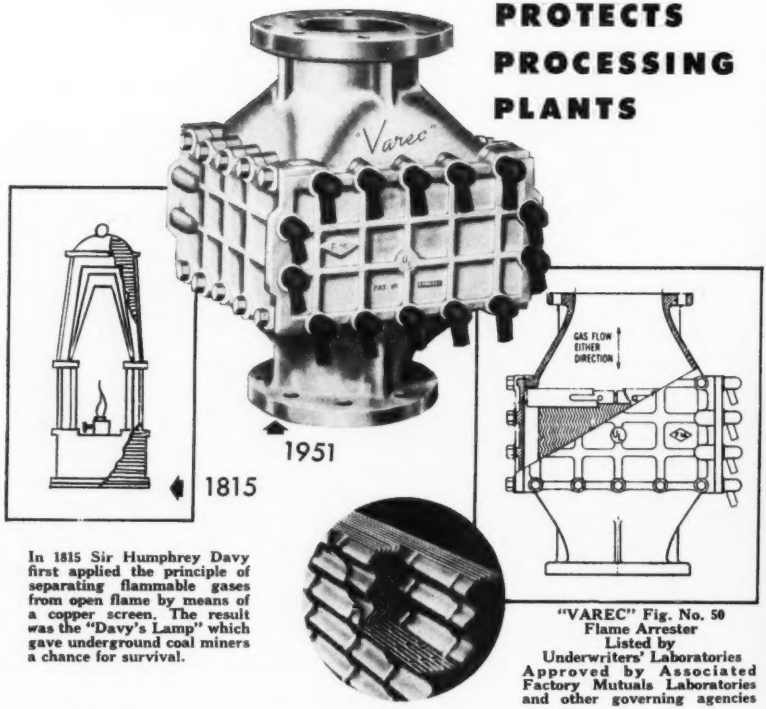
NAME..... POSITION.....

FIRM NAME.....

ADDRESS.....

CITY..... ZONE..... STATE.....

THIS MODERN "Davy's Lamp" PROTECTS PROCESSING PLANTS



In 1815 Sir Humphrey Davy first applied the principle of separating flammable gases from open flame by means of a copper screen. The result was the "Davy's Lamp" which gave underground coal miners a chance for survival.

"VAREC" Fig. No. 50 Flame Arrester Listed by Underwriters' Laboratories Approved by Associated Factory Mutuals Laboratories and other governing agencies

"VAREC" FLAME ARRESTERS utilize this age-old basic principle of heat transfer in protecting plants, equipment and lives against fire and explosion wherever gas or flammable liquids are stored.

They stop burning gas in piping from rapidly propagating thus preventing fire and explosion. Heat of the flame is dissipated through the many surfaces of the multiple corrugated aluminum plates within the unit. Resultant heat loss, plus the tortuous passageways through which the flame would have to pass, stops flame propagation just as the copper screen did in the "Davy's Lamp."

"Varec" Flame Arresters are a low cost investment in the utmost safety for your plans . . . consult your "Varec" representative or write direct.

NF 2

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

Cable Address: VAREC COMPTON USA (All Codes)

"THE *MASTER* OF *FLAME*"

ANSUL

DRY CHEMICAL FIRE EXTINGUISHING EQUIPMENT

FIRST . . . in advanced engineering design and functional dependability . . .

FIRST . . . in fire-stopping effectiveness with inexperienced operators . . .

. . . . . Your BEST PROTECTION FOR FLAMMABLE LIQUID, GAS AND ELECTRICAL FIRES

MODEL 20-B

Ansul Dry Chemical Fire Extinguishers were FIRST with the GREATEST FIRE-KILLING RATINGS ever attained by hand and wheeled portable fire extinguishers*. No type or make of extinguisher has ever exceeded Ansul's effectiveness ratings for flammable liquid fires.

Ansul features include: 1) Patented nozzle which provides the most effective stream pattern for quick extinguishment of fires . . . in addition to forming a heat-shield for the operator. 2) Water-tight and corrosion-resistant construction. 3) Easy, on-the-spot recharging after use without special tools . . . and many others.

● Ansul Chemical Company is the *only* fire extinguisher manufacturer maintaining extensive chemical research laboratories in addition to a large engineering staff for research and development to maintain and improve the quality of its products . . . *Plus* the most extensive, best-equipped proving grounds in the industry.

*Get the facts. See comparative effectiveness ratings for various types of approved fire extinguishers based on tests by nationally recognized approval agencies. Write for file No. 813. You will receive complete information and other valuable data.

Ansul *"PLUS-FIFTY"*® Dry Chemical is non-corrosive, non-abrasive and non-toxic. It is safe to use on electrical fires of any voltage. And ANSUL extinguishers need only be inspected annually, NOT RECHARGED, adding ECONOMY to GREATER FIRE-STOPPING EFFECTIVENESS.

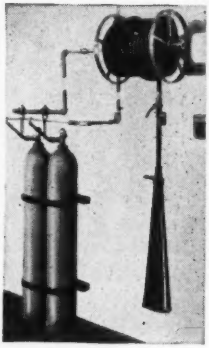
ANSUL CHEMICAL COMPANY

Fire Extinguisher Division
MARINETTE • WISCONSIN

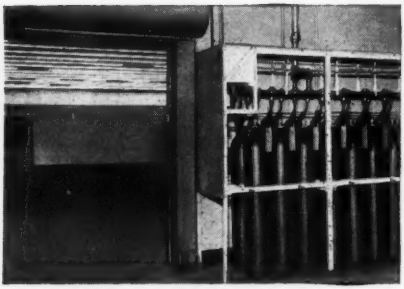
OFFICES AND DISTRIBUTORS IN PRINCIPAL CITIES IN THE U. S. A., CANADA AND OTHER COUNTRIES
ALSO MANUFACTURERS OF INDUSTRIAL CHEMICALS, REFRIGERANTS AND REFRIGERATION PRODUCTS

Protection against FIRE in Fixed-Position Hazards?

RELY ON *KIDDE* CO_2 BUILT-IN SYSTEMS, HOSE RACKS, REELS!



Kidde Hose Racks and Reels permit fire fighting anywhere within a wide radius of fixed position of rack or reel.



Kidde Built-in Systems are individually engineered for the protection of fixed-position hazards. Operation may be manual or automatic. Several hazards can often be protected from a single bank of cylinders.

Kidde

Kidde Extinguishers carry highest rating of Underwriters' Laboratories and The Factory Mutuals

Kidde

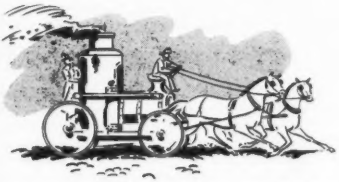
Walter Kidde & Company, Inc., 151 Main St., Belleville 9, N. J.
Walter Kidde & Company of Canada, Ltd., Montreal, P. Q.

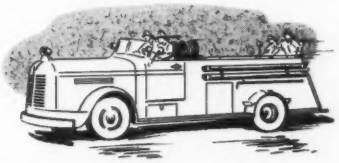
Now! Fenwal

DETECT-A-FIRE

unit brings you unique, new

rate compensation fire detection





AS DIFFERENT from existing principles of fire detection as the fire-fighting equipment above!

Why risk *lives* and costly property replacement due to undetected fires? With unique, DETECT-A-FIRE units you do away with time lag, false alarms. Based on a new rate-compensation principle of fire detection, these units respond *only* when the temperature of the surrounding air reaches predetermined danger level. Recommended for plants, ships, institutions, commercial, mercantile, and public buildings. Listed by Ⓤ. Approved by Ⓐ — U. S. Coast Guard.

PLEASE SEND ME THE BASIC FACTS about the new Fenwal DETECT-A-FIRE unit for institutional, commercial, mercantile, industrial, and marine locations.

Name ..... *Position* .....

Company .....

Street .....

City ..... *Zone* ..... *State* .....

Fenwal

DETECT-A-FIRE

Precise, DYNAMIC Fire Detection

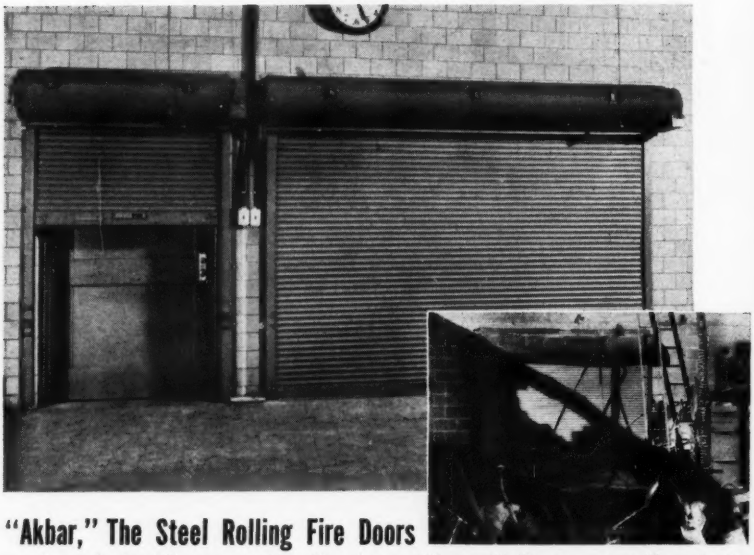
FENWAL, INCORPORATED

141 Pleasant Street, Ashland, Mass.

Los Angeles, Cal.

Temperature Control Engineers

"Akbar" Doors Automatically Block Flames—*with Safety*—at Hazardous Openings



"Akbar," The Steel Rolling Fire Doors made only by Kinnear, stop fire by cutting off flame-spreading drafts

Kinnear's famous AKBAR Steel Rolling Fire Doors give you *quick, positive,* automatic protection. When fire threatens, they stop dangerous flame-spreading drafts, by blocking openings with a curtain of steel.

Yet their automatic action features special provisions for the safety of building occupants. In emergency release, they are pushed down by a strong starting spring, to assure positive action. Their downward speed is controlled as a safety measure for anyone passing underneath as the doors are released.

Another device stops the door positively at floor level—with the steel door curtain covering the entire opening. The door won't sag, or drop through a fire-weakened sill. In addition, the doors may be opened after automatic closure, for emergency escape.

When not in use, Akbar Doors remain coiled overhead, out of the way. Approved and labeled by Underwriters' Laboratories, Inc., they have saved as much as *one third of their cost per year,* in reduced insurance rates. They are built to fit horizontal openings of any size. Write today for complete information.

Akbar Doors can be equipped for daily service use, with motor operation if desired. However, the regular Kinnear Steel Rolling Doors (non-labeled) are designed for service use where maximum fire protection is not required.

Saving Ways in Doorways
KINNEAR
ROLLING DOORS

The KINNEAR Manufacturing Co.
FACTORIES: 2250-70 Fields Ave., Columbus 16, O.
1742 Yosemite Avenue, San Francisco 24, Calif.
Offices and Agents in All Principal Cities

YOUR OWN FIRE DEPARTMENT!

. . . a fire department that's on duty 24 hours a day, without vacations and without "pay"—safeguarding your property . . . preventing loss of life . . . protecting your profits . . . insuring employees' positions!

Your yearly insurance savings applied to the cost of a Blaw-Knox Automatic Fire Protection System converts an existing expense into a capital asset. Reductions from 50 to 90% are effected by this fully recognized fire protection—quickly amortizing the entire cost.

"LITTLE JOEY SPRINKLER"

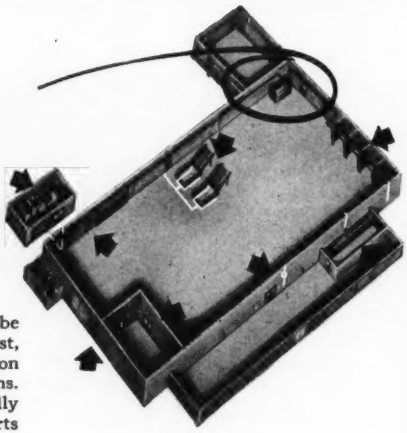
At your request a Blaw-Knox Engineer will make a survey of your fire hazards, secure your insurance underwriter's requirements, prepare a preliminary layout of a system that will give you the utmost in fire protection, and submit an estimate of costs—all without obligation.

BLAW-KNOX SPRINKLER DIVISION
OF BLAW-KNOX CONSTRUCTION COMPANY
829 Beaver Ave., N.S., Pittsburgh 33, Pa.
Offices in Principal Cities

BLAW-KNOX FIRE PROTECTION SYSTEMS

Plant-Wide Fire Protection

from a single LOW PRESSURE CARBON DIOXIDE storage tank



Now, your larger size fire hazards can be protected more efficiently at less cost, thanks to C-O-TWO Low Pressure Carbon Dioxide Type Fire Extinguishing Systems. Simple piping, running from one centrally located storage tank, instantly transports clean, non-damaging, non-conducting carbon dioxide anywhere in the plant area . . . to flammable liquids, electrical equipment, storage spaces, manufacturing processes and record vaults. Fire at any protected location is extinguished in seconds with an absolute minimum of expense and interruption.

Flexibility is the keynote of these new type C-O-TWO Fire Extinguishing Systems . . . the low pressure carbon dioxide storage tanks range in capacities from one to fifty tons . . . discharge facilities can either be manual mechanical, manual electric, automatic mechanical, automatic electric or a combination of these . . . especially installed to fit your particular needs. Future plant expansion is easily and economically provided for by initially installing an oversized low pressure carbon dioxide storage tank and adding the supplementary discharge facilities at a later date.

C-O-TWO Low Pressure Carbon Dioxide Type Fire Extinguishing Systems are built with the same superior design and high quality workmanship that have characterized C-O-TWO High Pressure Carbon Dioxide Type Fire Extinguishing Systems for many years. Whether it's fire detecting or fire extinguishing . . . portables or built-in systems . . . C-O-TWO means experienced engineering that assures you of the best type equipment for the particular fire hazard concerned.

So, with current expensive delayed replacements, why not let an expert C-O-TWO Fire Protection Engineer help you now in planning fully approved fire protection facilities for your various properties. Complete free information and descriptive literature is yours for the asking. Get the facts today!

C-O-TWO

C-O-TWO FIRE EQUIPMENT COMPANY

NEWARK 1 • NEW JERSEY

Sales and Service in the Principal Cities of United States and Canada

Affiliated with Pyrene Manufacturing Company

MANUFACTURERS OF APPROVED FIRE PROTECTION EQUIPMENT

Squeez-Grip Carbon Dioxide Type Fire Extinguishers • Dry Chemical Type Fire Extinguishers
Built-In High Pressure and Low Pressure Carbon Dioxide Type Fire Extinguishing Systems
Built-In Smoke and Heat Fire Detecting Systems

More than 300 Birch Weldwood Fire Doors are used in the new building for the Institution of Physical Medicine and Rehabilitation, a unit of New York University — Bellevue Medical Center.

ACCEPTED... APPROVED and GUARANTEED!

...The Weldwood® Fire Door!

Here at last is a fire door that performs its number one function — restricting the spread of fire—yet is so handsome that it can be used in the finest interior.

The secret lies in the unique construction—the choicest of domestic and imported wood veneers are bonded to an incombustible mineral core.

The Weldwood Fire Door is approved for Class "B" and "C" openings by Underwriters' Laboratories, Inc. and the Building Officials Conference of America.

In addition, the Weldwood Fire Door is so dimensionally stable that when properly installed it is guaranteed not to bind or warp for the life of the installation.

Further, it is lighter in weight than other fire doors, which means that it opens and closes more easily.

No wonder Weldwood Fire Doors have the acceptance of fire officials . . . and are being selected for all kinds of buildings — all over the country. (*Including* the United Nations Building in New York.)

So, before you specify *any* door, be SURE to get full details about Weldwood Fire Doors. *Write today.*

United States Plywood Corporation carries the most complete line of flush doors on the market including the famous Weldwood Fire Doors, Weldwood Stay-Strate Doors, Weldwood Honeycomb Doors, Mengel Hollow-core Doors, Mengel and Algoma Lumber Core Doors, 1⅜" and 1¾" with a variety of both foreign and domestic face veneers.

Weldwood®

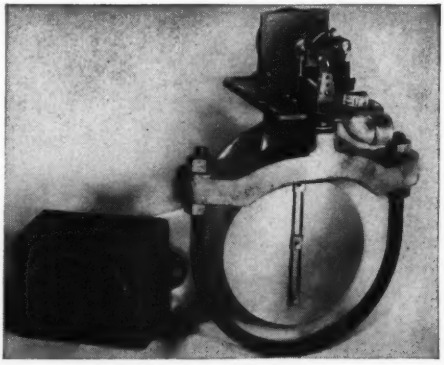
WELDWOOD® FLUSH DOORS

Manufactured and distributed by

UNITED STATES PLYWOOD CORPORATION

55 West 44th Street, New York 18, N. Y.

Branches in Principal Cities • Distributing Units in Chief Trading Areas • Dealers Everywhere



5-inch size shown above. To install simply drill hole in pipe.

CENTRAL STATION SIGNALS, INC. Model PRS

Waterflow Alarm Device is approved by both the Factory Mutual Laboratories and Underwriters' Laboratories, Inc. In hundreds of installations it has proved to be the ideal alarm device for sprinkler systems.

SAVE VITAL MATERIALS! Install this water flow alarm device in place of bulky alarm valves. Only 10 oz. of vital material used in our water flow switch.

- **Made in all sizes from 2½" to 8"**
- **It is positive in operation**
- **Has instantly recycling pneumatic retarding device which prevents false alarms**
- **Has enclosed electrical contacts for 15 amp, 125 volts AC and ½ amp, 125 volts DC**

By installing this most economical alarm device, you will know instantly where the water is flowing. Many plants are having them installed on each floor or in each section. They save water damage.

This device can also be obtained as Model PRT, a coded waterflow transmitter from which signals are received on a punch register and single stroke gong. Practically any number can be installed on a two-wire system, thus resulting in considerable savings on wiring.

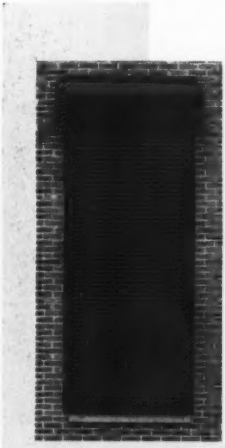
WE SOLICIT YOUR INQUIRIES

CENTRAL STATION SIGNALS, INC.

Manufacturers of all kinds of approved devices used in Central Station Systems or Class 'A' or Class 'B' Proprietary Fire Alarm Systems, either automatic or manual.

71 WEST 23rd STREET -:- NEW YORK 10, N. Y.

Automatic Rolling Steel
FIRE DOORS *and* WINDOW SHUTTERS
PREVENT SPREAD *of* FIRE!

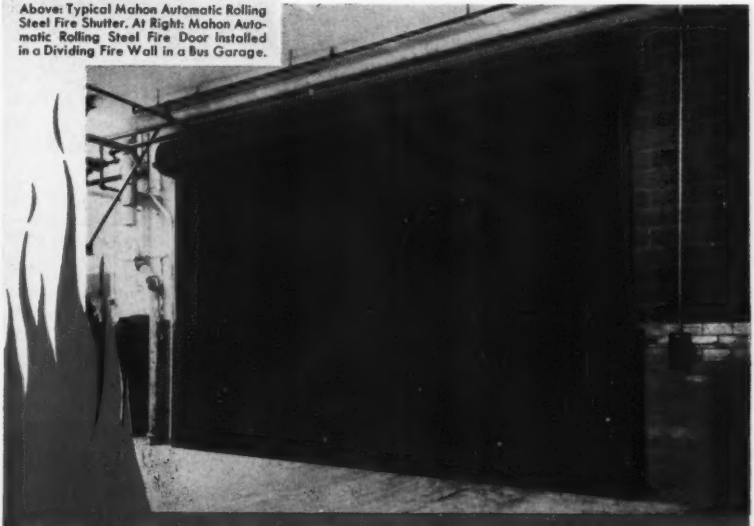


You need good automatic fire doors in fire walls, corridors, and vertical shafts . . . in some cases automatic rolling steel window shutters are necessary to protect your building and its contents from fires which may originate in nearby buildings. Many, many cases are on file which confirm that timely action of automatic rolling steel fire doors and window shutters have confined a fire to its point of origin and permitted its being extinguished with comparatively small damage. Make a survey of your building now, and don't delay action. You will find a Mahon Automatic Rolling Steel Fire Door or Window Shutter to meet each of your requirements—all bear the Underwriters' Label. These automatic fire doors may be operated manually or mechanically in every day use. If a fire should break out while they are in the open position, the automatic mechanism will close the door, cutting off drafts and preventing the spread of the fire. See Sweet's Files for complete information, or ask for Catalog G-52.

THE R. C. MAHON COMPANY
Detroit 34, Michigan • Chicago 4, Illinois

Manufacturers of Automatic Rolling Steel Fire Doors and Window Shutters. Also Many Types of Standard General Service Rolling Steel Doors and Grilles, Insulated Metal Walls, and Steel Deck for Roofs, Floors and Partitions.

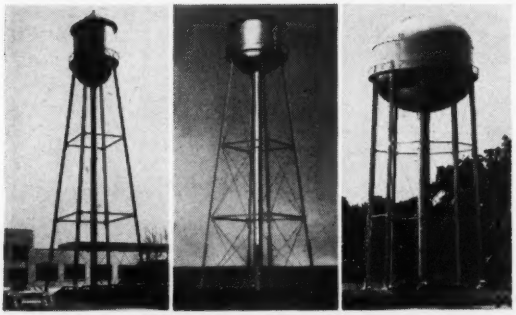
Above: Typical Mahon Automatic Rolling Steel Fire Shutter. At Right: Mahon Automatic Rolling Steel Fire Door Installed in a Dividing Fire Wall in a Bus Garage.



MAHON ROLLING STEEL FIRE DOORS and WINDOW SHUTTERS

PITTSBURGH • DES MOINES ***INDUSTRIAL***

Elevated Steel Tanks



Choose the Pittsburgh-Des Moines Elevated Steel Tank meeting your precise requirements in type and capacity, and you will enjoy every benefit of safe and certain water supply—at lower cost —*with guaranteed dependability*. Write for our latest "Modern Water Storage" Brochure.

PITTSBURGH • DES MOINES STEEL CO.

Plants at PITTSBURGH, DES MOINES and SANTA CLARA

Sales Offices at:

PITTSBURGH (25). . . . 3468 Neville Island
NEWARK (2). . . 250 Industrial Office Bldg.
CHICAGO (3). 1272 First National Bank Bldg.
DES MOINES (8). . . . . 969 Tuttle Street
DALLAS (1). . . . 1273 Praetorian Building
SEATTLE . . . . . 576 Lane Street
SANTA CLARA, CAL. . . 675 Alviso Road

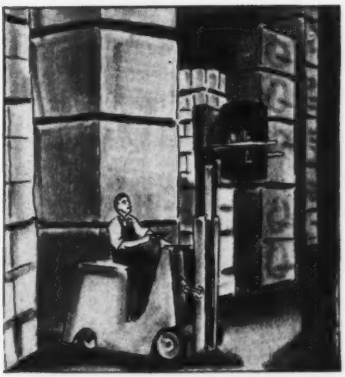
BETTER FIRE PROTECTION with Less Water

NEW ROCKWOOD T-HEAD

Rockwood T-Heads provide better and more effective protection against fires in flammable liquids and ordinary combustibles. Fires are controlled and extinguished faster with less water—and fewer heads are needed to do a better job. All distribution of water is discharged down into flame space, giving better control of fire. Better ceiling protection is obtained from Rockwood T-Heads — no water is discharged directly onto ceiling. Picture above shows Rockwood T-Heads forming an excellent water curtain in a large grease plant. Water pattern from T-Heads overlap near ceiling — stops hot gases from mushrooming along ceiling.

Write for illustrated Folder, today.

Approved by Underwriters' Laboratories, Inc. and Factory Mutual Laboratories.



New handling equipment allows plant owners to stock materials in higher piles. This method presents a serious fire hazard. Rockwood T-Heads in recent fire tests have proven to be the best fire protection in such overcrowded storage conditions.

The T-Head that will Revolutionize Sprinkler Protection!

ROCKWOOD

ROCKWOOD SPRINKLER CO.

56 HARLOW STREET WORCESTER 5, MASS.

Experienced Engineering • Specialized Manufacturing • Expert Installation

SAFER

liquid handling for Industry

THIS NEW TOKHEIM HAND PUMP contributes to safer handling of volatile liquids wherever used. Stops wasteful dripping and slippery floors. Reduces fire hazard and accidents common to other methods of liquid transfer. Approved for handling petroleum liquids—ideal for many others. Available in hose and spout models—for drums, skid tanks and underground installations. Order from your dealer, your oil company or your Tokheim representative. **Write factory for literature.**

General Products Division

TOKHEIM OIL TANK AND PUMP COMPANY

1686 Wabash Avenue, Fort Wayne 1, Indiana

Factory Branch: 1309 Howard Street, San Francisco 3, California

RELIABLE

AUTOMATIC SPRINKLER DEVICES

PROTECTING LIFE AND PROPERTY FOR OVER 25 YEARS

Reliable Automatic Sprinkler Devices have an excellent field record . . . superb in design and construction . . . are universally approved by all Fire Insurance and Governmental Authorities . . . and effect maximum reductions in fire insurance premiums.

They comprise a complete line including Automatic and Open Sprinklers, Alarm Valves, Dry Pipe Valves, Accelerators, Circuit Closers, Water Motors and all other accessories required in Sprinkler Systems.

PROMPT SERVICE BY LOCAL RELIABLE REPRESENTATIVES

Experienced Reliable Representatives are located throughout the United States, in Canada and foreign countries. These local organizations can install a Reliable Automatic Sprinkler System designed for each particular requirement. Write us for the name of the Reliable Representative nearest you.

FURTHER INFORMATION ON REQUEST

Manufactured and Distributed by

The Reliable Automatic Sprinkler Co. Inc.

BRONX STREET MOUNT VERNON N. Y.

OWENS-CORNING
FIBERGLAS CONSTRUCTION MATERIALS

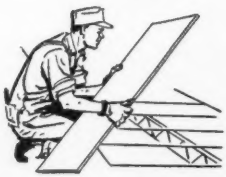
. . . CONTRIBUTE TO FIRE SAFETY

For rating engineers, use of Fiberglas Construction Materials means *greater* fire protection . . . more *lasting* protection because of the natural properties of the basic material, namely ageless fibers of glass which will neither burn nor support combustion. Notable examples are:

FIBERGLAS ACOUSTICAL TILE . . . Listed by the Underwriters' Laboratories, Inc.—Non-combustible under Federal Spec. SS-A-118a—Non-combustible under ASTM, E 84-50 T.

FIBERGLAS COATED DUCT INSULATION . . . Listed by the Underwriters' Laboratories, Inc. Based on UL tests, universally accepted as a fire-retardant material . . . also no toxic fumes. Smoke developed is negligible.

FIBERGLAS INSULATING FORM BOARD . . . Rated non-combustible under Fed. Spec. SS-A-118a. A roof material used as a form board for poured-in-place gypsum and lightweight aggregate roof decks. Possesses enduring fire safety, excellent insulating and noise reduction properties.



OWENS-CORNING FIBERGLAS CORPORATION
Dept. 117A • Toledo 1, Ohio

*Fiberglas is the trade-mark (Reg. U. S. Pat. Off.) of the Owens-Corning Fiberglas Corporation for a variety of products made of or with fibers of glass.

HORTON WATERSPHERE

provides gravity water supply

This 75,000-gallon Watersphere has been installed at St. Ann's Home for the Aged in Techny, Ill. It provides gravity water supply for general service and will be the primary source of maintaining water pressure for the automatic sprinkler system. The water supply is obtained from wells on the premises.

St. Ann's Home is conducted by the Missionary Sisters, Servants of the Holy Ghost. It was established in 1903 and has a ground area of 11.5 acres. Facilities consist of the (1) Main building housing both men and women, (2) the Annex, housing men only and (3) the Infirmary, housing the Mild Mental, women only. The total population of the Home, including Sisters and employees, is 330.

Write our nearest office for prices on elevated tanks. State capacity, height to bottom and location.

CHICAGO BRIDGE & IRON COMPANY

CLEVELAND	CHICAGO	BIRMINGHAM	LOS ANGELES
HAVANA	DETROIT	ATLANTA	WASHINGTON
HOUSTON	TULSA	NEW YORK	PHILADELPHIA
SEATTLE	BOSTON	HAVANA	SAN FRANCISCO

Plants at Chicago, Birmingham, Salt Lake City and Greenville, Pa.

Introducing

THE

STAR

Automatic

SPRAY NOZZLE

MODEL FM-C

For More Efficient Extinguishment of Fire in Extra-Hazardous Materials

Designed and approved for better extinguishment in rubber tires and other high-piled storage and in occupancies where special hazards exist. The Star Type FM-C Automatic Spray Nozzle uses water more efficiently and effectively — all discharged water going directly into the fire below. The cooling effect produced by the overlapping discharge of water from the heads prevents combustion at the ceiling. Thus, fewer heads operate and less water is utilized — A MOST IMPORTANT MILESTONE IN THE PROGRESS OF MODERN FIRE PROTECTION!

Write us for name and address of the
Star licensed contractor nearest your location

Licensees in all principal cities — and in Canada

STAR SPRINKLER CORP.

Westmoreland and Collins Sts. — Philadelphia 34, Pa.

Are Your Employees Organized for FIRE SAFETY?

NEW Edition of NFPA Booklet

"Employee Organization for Fire Safety"

Outlines Program

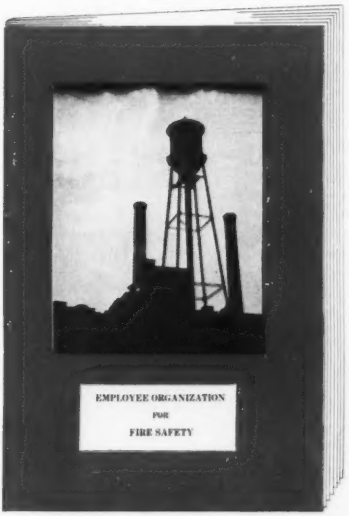
●

Single Copy 50¢

Special quantity discounts for one shipment:

25 to 500 copies, 25% discount

500 and over, 33⅓% discount



Size 6" x 9"—44 pages—2 colors.

Employees, foremen, plant fire brigades, fire protection engineers, department heads and plant managers will find this 44-page illustrated booklet a valuable guide to fire safety. While this text describes an employee fire safety organization for industrial plants, the same principles apply to department stores, hotels, apartments, mercantile buildings, office buildings, schools, institutions and other occupancies.

BE PREPARED... BE PREPARED FOR FIRE SAFETY!

ORDER FROM

NATIONAL FIRE PROTECTION ASSOCIATION

INTERNATIONAL

60 Batterymarch St., Boston 10, Mass.

WELL PLANNED ECONOMY

GLOBE
SPRINKLERS
FIREMEN EVERY 10 FEET
Lower Production Cost. America's huge FIRE waste is an overhead charge on production . . . an unfair burden on our manufacturers now competing for world trade. Control the FIRE menace. Let GLOBE Sprinklers protect your plant.
GLOBE AUTOMATIC SPRINKLER CO.
NEW YORK . . . CHICAGO . . . PHILADELPHIA
Offices in nearly all principal cities
THEY PAY FOR THEMSELVES

You know how to operate this extinguisher ... JUST BY LOOKING AT IT!

2½ and 4 lb. Models. Famous "one hand" instant operation.

25 lb. Model. Mobile defense against severe, large-area fires. One man operation.

10 lb. Model. Long-range hose and nozzle, easily portable.

Simple, ***obvious*** operation makes the Randolph really panic-proof—gets it into action ***before*** the fire spreads —kills fire instantly with a snowy cloud of CO_2! No valves to turn, no nozzles to adjust; just point and press your thumb! Randolph CO_2 is non-damaging, evaporates without a trace. It's safe, won't conduct electricity, deteriorate or freeze.

UNDERWRITERS' APPROVED — COMPLETE LINE OF EXTINGUISHERS AND SYSTEMS. Learn how Randolph gives your plant better preventative fire protection! Write or wire:

RANDOLPH Laboratories, Inc.,
24 E. Kinzie St., Chicago 11, Ill.

15 lb. Model. Self-balanced extra range and capacity.

Randolph
SIMPLIFIED FIRE EQUIPMENT

★ 1920 ★ 1952 ★

32 YEARS OF SUPERIOR SERVICE

Prove

CENTRAL AUTOMATIC SPRINKLER SYSTEMS

Your BEST PROTECTION against the fury of FIRE

Whether it be a wet pipe system or a dry pipe system — or perhaps a Central "Electro-Speed" Deluge Sprinkler System, you will find the one BEST TYPE is a CENTRAL SPRINKLER SYSTEM.

They pay for themselves in insurance savings.

Write us for information.

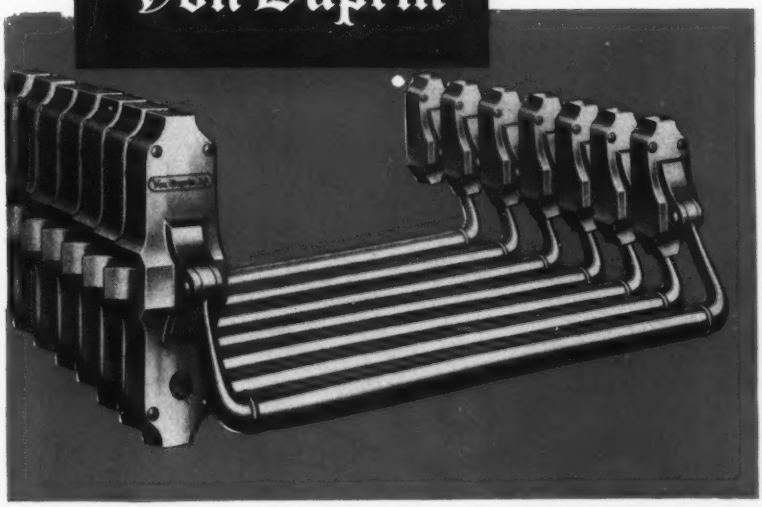
CENTRAL AUTOMATIC SPRINKLER COMPANY

Main Office and Plant
Fourth Street and Cannon Avenue
LANSDALE, PA.
(Representatives in principal cities in United States, Canada and foreign countries)

"Central Sprinklers answer the burning question"

★ 1920 ★ 1952 ★

Von Duprin



Builders of Fire and Panic Exit Devices Since 1908

● Back in 1908, Von Duprin built the very first panic device. Ever since that time, Von Duprin has been the leader in this highly specialized field . . . the leader in design, manufacturing and sales.

Each new design and development has had one prime purpose: to assure—*always*—safe exit in time of emergency.

Von Duprin devices—many of them serving heavy traffic with no major repairs for over 40 years—deliver dependable, day-in, day-out service with minimum maintenance.

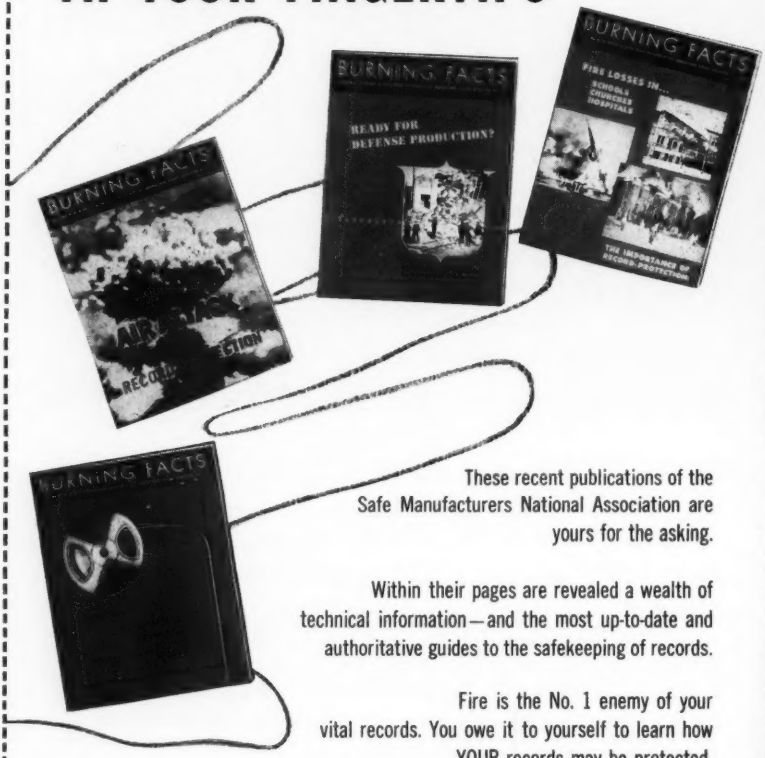
Von Duprin offers a nation-wide group of trained consultants whose job it is to review particular installation requirements and recommend the *right* device—without obligation.

VONNEGUT HARDWARE CO.
VON DUPRIN DIVISION
INDIANAPOLIS 9, INDIANA

Von Duprin PANIC DEVICES ASSURE SAFE EXIT

UL

A GALLERY OF INFORMATION AT YOUR FINGERTIPS



These recent publications of the Safe Manufacturers National Association are yours for the asking.

Within their pages are revealed a wealth of technical information—and the most up-to-date and authoritative guides to the safekeeping of records.

Fire is the No. 1 enemy of your vital records. You owe it to yourself to learn how YOUR records may be protected.

Write today for one or more of the above titles. They will be forwarded promptly, and without charge, upon receipt of your request on your business letterhead.

SAFE MANUFACTURERS NATIONAL ASSOCIATION, Inc.
366 MADISON AVE., NEW YORK 17, N. Y.

In The Background Till Fire Strikes

Fits in smoothly with the most modern interiors. Barely visible, but ready at a second's warning to spring into action. Viking Flush Type Sprinkler Heads offer great *dependability*, plus true functional design. Get all details today from the *Viking* representative in your neighborhood.

THE VIKING FLUSH TYPE SPRINKLER HEAD

VIKING CORPORATION REPRESENTATIVES

Crawford & Slaten Co.
Atlanta, Georgia

Crawford Sprinkler Co.
Charlotte, North Carolina

Hudson Viking Sprinkler Co.
St. Paul, Minnesota

C.W. Hutchinson, Inc.
Huntington, West Virginia

Texas Automatic Sprinkler Co.
Dallas, Texas
Houston, Texas
San Antonio, Texas
Jackson, Mississippi
Memphis, Tennessee
New Orleans, Louisiana
Oklahoma City, Oklahoma
Little Rock, Ark.

Walton Viking Co.
Kansas City, Missouri
St. Louis, Missouri
Omaha, Neb.

Viking Sprinkler Co., Inc.
Boston, Massachusetts

Viking Automatic Sprinklers, Inc.
Buffalo, New York

Viking Automatic Sprinkler Co.
Chicago, Illinois

Viking Sprinkler Co.
Cincinnati, Ohio
Cleveland, Ohio
Indianapolis, Indiana

Viking Sprinkler Co.
Detroit, Michigan

Viking Sprinkler Co.
Grand Rapids, Michigan

California Viking Sprinkler Co.
Los Angeles, California

Viking Sprinkler Co.
New York, New York

Viking Sprinkler Co.
Philadelphia, Pennsylvania
Pittsburgh, Pennsylvania

Viking Automatic Sprinkler Co.
Seattle, Washington
Portland, Oregon
Vancouver, B. C.

THE VIKING CORPORATION
HASTINGS, MICHIGAN

ROLAGRIPS

THE COUPLING FOR PLAIN END PIPE

now listed by FACTORY MUTUAL LABORATORIES

for use on sprinkler systems

Rolagrip pipe couplings are now listed by Factory Mutual Laboratories for use on sprinkler systems.

Rolagrips are for plain end pipe — no threading, grooving, flanging or welding is necessary. Rolagrips are easy to apply— no special tools or skills are required. Every joint becomes a flexible union; every joint can be easily dismantled for repair or clean-out. Rolagrips withstand shock, end pull, vibration, expansion and contraction, and are especially convenient on cut-ins.

Rolagrip couplings are available in sizes 1½" - 12" for use on plain-end steel or wrought iron pipe, new or used. Gustin-Bacon also offers Gruvagrip couplings for grooved pipe, now listed by Factory Mutual Laboratories for use on sprinkler systems.

WRITE TODAY FOR PICTURES, PRICES, STRESS CHARTS, FULL DETAILS ON THESE TIME-TESTED COUPLINGS, NOW AVAILABLE TO THE FIRE PROTECTION INDUSTRY.

GUSTIN-BACON MANUFACTURING CO.

210 W. 10th ST. KANSAS CITY, MO.

ENGINEERED Foam Fire Protection

Increased use of gasoline, alcohols, acetone, or other flammable liquids creates serious hazards you may have overlooked in your plant. Check your present protection facilities now so you can meet sudden emergencies with fast, positive, fire-killing foam.

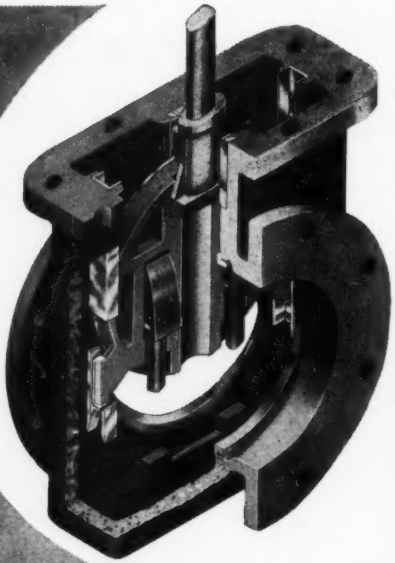
National Foam engineers can survey your plant, study risks involved, and then determine the type of *foam protection* best suited to your plant's requirements . . . mechanical or chemical foams . . . the most complete choice of devices available . . . Foam Chambers for large tanks, Overhead Spray Deflectors, Nozzles, Dip Tank or Drainboard Systems, or even small extinguishers and other devices . . . whichever is best suited to your particular needs. Large plant, or small, National Foam specialists are ready to *engineer* foam protection to meet the hazards of your plant.

Let National Foam engineers and chemists show you how to get the best *foam* fire protection today! Consult your nearest National Foam Distributor, or write us direct about your problem.

NATIONAL
FOAM SYSTEM, INC.
Headquarters for Foam Fire Protection
WEST CHESTER, PENNA.

NATIONAL FOAM CONTINUOUS FOAM PRODUCTION SYSTEM

MH



DOUBLE SQUARE BOTTOM

GATE VALVES

When it is desired to install a gate valve for throttling purposes, or in a vertical pipe line, M & H double square bottom valves have many important advantages.

When valve is opened, each of the three shoes on both discs immediately contact the feathered edge of the tracks. These three contacts result in the disc being eased away instantly from the seat. The shoes then ride the tracks squarely and firmly for the full travel of the disc. In closing, discs ride the tracks down to a point exactly opposite the valve seat. At that point, the discs are clear and free to seat by action of the two spreaders, each functioning independently of the other.

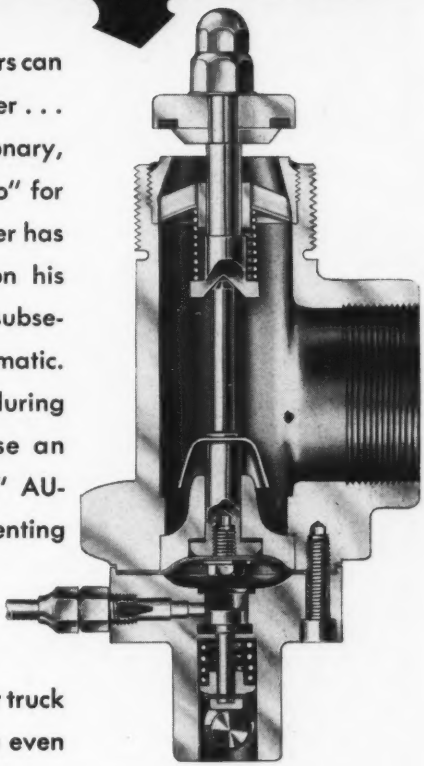
M & H double square bottom valve prevents the down stream gate from tilting into the down stream port opening and by chatter or vibration damaging the seat and gate rings. These valves can be installed with either disc on the down stream side.

Available in classes A, B, and C, sizes 3″ and larger. Where needed, can be supplied with rollers; or roller, tracks and scrapers. For complete information, write or wire M & H Valve and Fittings Company, Anniston, Alabama.

M&H PRODUCTS *Everywhere*

FASTER DELIVERIES

Now your drivers can make LP-Gas deliveries faster . . . and SAFER with the revolutionary, new Shand & Jurs "Safetiflo" for LP-Gas truck tanks. The driver has only to prime the valve on his initial delivery to make subsequent operation fully automatic. Should ANY accident occur during delivery that would cause an excess flow, the "Safetiflo" AUTOMATICALLY closes, preventing further discharge of LP-Gas. Yes, the S&J "Safetiflo" will help your drivers make more deliveries per truck per day . . . and provide even GREATER SAFETY.



UL

Shand and Jurs Co. 8TH & CARLTON STS. • BERKELEY, CALIFORNIA

New York Chicago Houston Tulsa Los Angeles Seattle

"Automatic" Sprinkler

10-point FIRE PROTECTION

YOU NEED IT...

only "Automatic" Sprinkler provides it!

Fire protection is serious business. A single automatic sprinkler may be called on to decide the fate of your company, whether it is a small single-plant operation or a large multi-million dollar corporation. Insist on *all* the plus values offered with *10 POINT Fire Protection*. Here's what you get:

1. **JOB SURVEY and ENGINEERING ANALYSIS: Detailed to meet individual needs.**
2. **BASIC FIXED TEMPERATURE SYSTEMS: Improved devices for fire detection and water extinguishment.**
3. **RATE-OF-TEMPERATURE-RISE PROTECTION: Recognized leaders in the development of high speed systems for all fire hazards.**
4. **QUALITY CONTROL: All system components—material and manufacture.**
5. **ACCURATE PREFABRICATION: Reduced installation time and expense.**
6. **QUALIFIED INSTALLATION CRAFTSMEN: Experienced in fire protection for all types of property.**
7. **NATIONWIDE ORGANIZATION: Expert fire protection engineers at your immediate service.**
8. **INSPECTION AND MAINTENANCE: Low cost service keeps fire-fighting equipment in fire-fighting condition.**
9. **CONTINUING RESEARCH: Constant improvement of old methods and development of new.**
10. **CONVENIENT PAYMENT CONTRACTS: Liberal lease, cash, or deferred plans permit payment out of savings.**

Your "Automatic" Sprinkler Fire Protection Engineer is as near to you as your telephone. Call him today. GET THE FACTS — ask for our informative 36-page book, "The ABC of Fire Protection". It's free!

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA

YOUNGSTOWN 1, OHIO

OFFICES IN PRINCIPAL CITIES OF NORTH AND SOUTH AMERICA

"Automatic" Sprinkler

FIRST IN FIRE PROTECTION

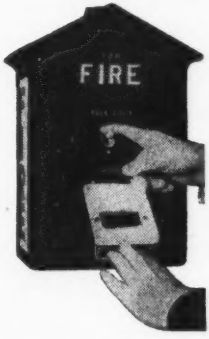
GAMEWELL

Municipal Fire Alarm Systems

Until the Fire Department knows there is a fire — and the exact location — it can do nothing about it.

For the protection of the values at risk — human life, property, business and income — adequate fire alarm box distribution is a sound investment.

The Standard Municipal Box

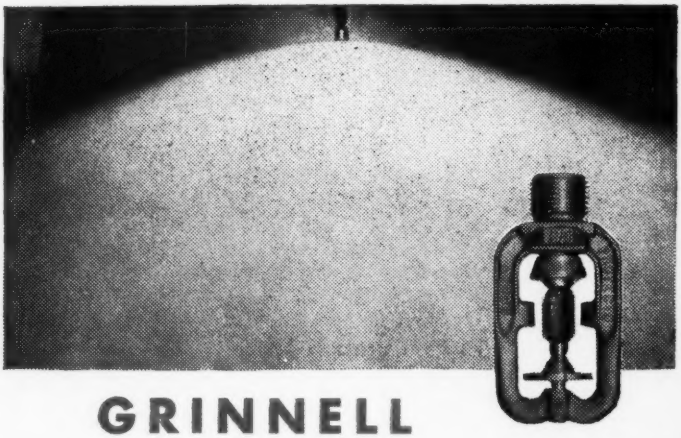


GAMEWELL Three-Fold Type

INDUSTRIAL FIRE ALARM SYSTEMS

We also supply complete systems for industrials and institutions. Write for our catalog descriptive of the Vigilarm System of Automatic Fire Detection.

THE GAMEWELL COMPANY
Newton Upper Falls 64 - Massachusetts



GRINNELL
Automatic ProtectoSpray*

The Grinnell Automatic ProtectoSpray Nozzle is the latest addition to a comprehensive line of spray nozzles. The actuating element is the same as in the Grinnell Quartzoid Sprinkler and is available in the same range of temperature ratings, protective coatings, and finishes. Three orifice sizes and six deflector angles meet various engineering requirements.

Recommended for risks involving high piled hazardous material where wide uniform coverage is desirable. Also for control or extinguishment of flammable liquid fires of all types, exposure protection for tanks containing such materials, and for blanketing openings in walls and sidings to prevent the spread of fire.

Information is available for the asking from any of our offices in principal cities. Grinnell Company, Inc., Providence 1, R. I.

*Reg. appl. for

GRINNELL SYSTEMS

For Protection Against Fire